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GUNNER'S MATE 2

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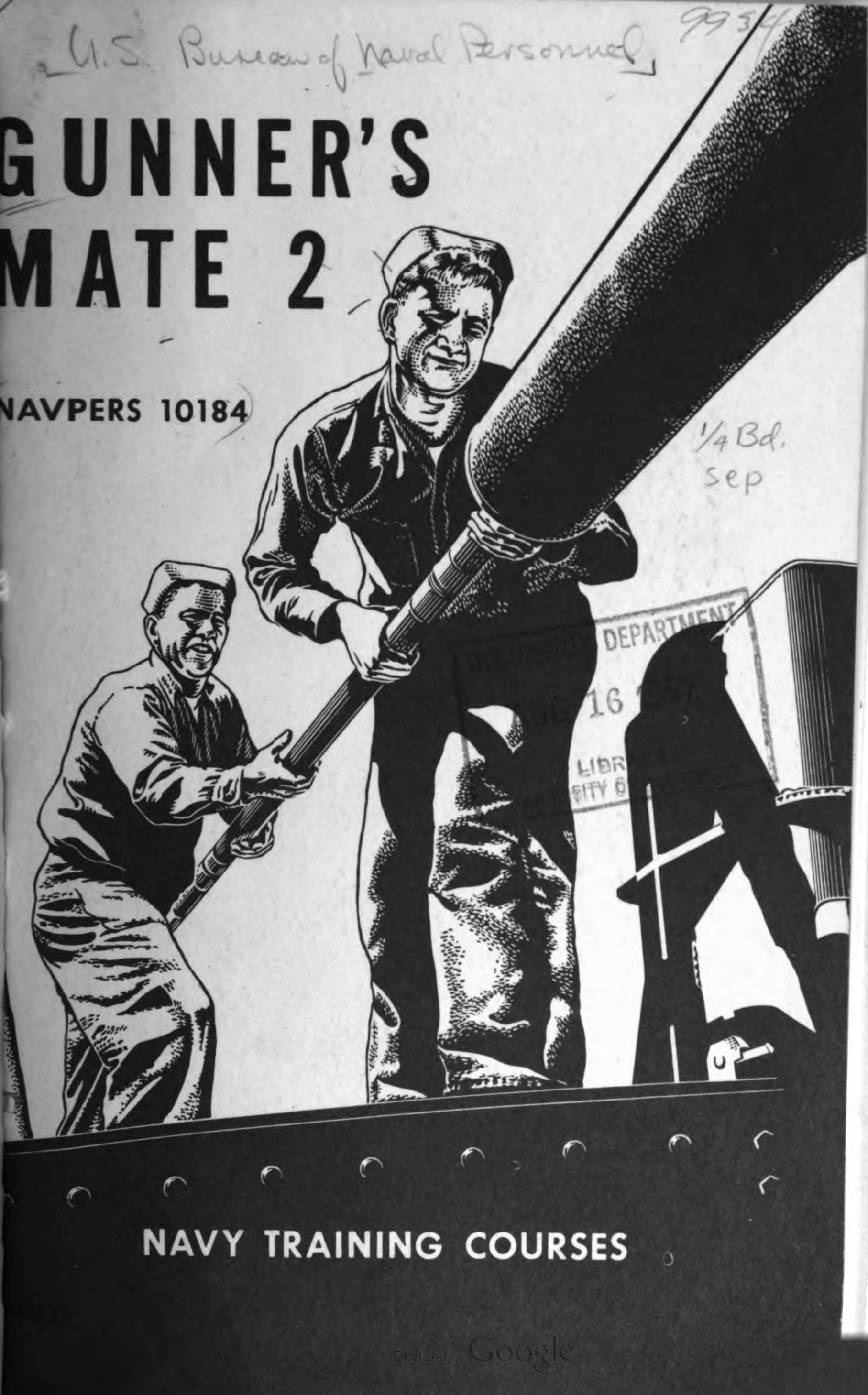

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NAVY TRAINING COURSES

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GUNNER'S MATE 2

Prepared by

BUREAU OF NAVAL PERSONNEL

L U. S.

(NAVPERS 10184)

NAVY TRAINING COURSES

NAVPERS 10184

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON: 1957

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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PREFACE

This one-volume course is designed to help you earn promotion to the rate of Gunner's Mate Second Class. Study of this course will help you to pass the written examination that you must take in order to attain this rate. Other materials that you may find it valuable to study along with this course are mentioned in the Reading List that appears on the page following this preface.

In appendix II at the end of this book are printed the present *Qualifications for Advancement in Rating* as they apply to the Gunner's Mate. (Check also with the current edition of the qualifications as published in NavPers 18068.) Use them as a guide in your studying. Although this course, with the others in this series, is primarily intended to take up examination subjects, you will find that it gives you valuable background information in connection with the practical tests that you must also take to earn promotion. Other suggestions for studying appear in chapter 1.

As one of the NAVY TRAINING COURSES, this book has been prepared by the Navy Training Publications Center for the Bureau of Naval Personnel, with the aid of technical review by the Advanced Gunner's Mate School, Naval Receiving Station, Washington, D. C.; and by the Bureau of Ordnance.

ACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
SERVICE	4 mos. service—or completion of recruit training.	3 mos. as E–2.	6 mos. as E–3 or 11 mos. total service.	12 mos. as E–4.	12 mos. as E–5; 6 mos. sea duty# as E–4 or E–5; total at least 36 mos.	36 mos. as E–6 including 6 mos. sea duty±
SCHOOL	Recruit Training.		Class A for PR3, PRS3.		Class B for MN1.	Class B for AGCA, MNCA, MUCA.
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.			
PRACTICAL FACTORS	Locally prepared check-offs.		Records of Practical Factors, NavPers 760, must be completed for all PO advancements.			
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.			
EXAMINATIONS	Locally prepared tests.		Service-wide examinations required for all PO advancements.			
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Required for E–3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed.				
AUTHORIZATION	Commanding Officer		U. S. Naval Examining Center			BuPers
	TARS are advanced to fill vacancies and must be approved by district commandants or CNARESTRA.					

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

#Sea duty not required of aviation ratings; CT, OM, JO, MA and CS ratings; men in L5 or L6; TARS or enlisted women.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*		E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
	FOR THESE DRILLS PER YEAR						
TOTAL TIME IN GRADE	24 OR 48 12 NON-DRILLING	9 mos. 9 mos. 12 mos.	9 mos. 15 mos. 24 mos.	15 mos. 21 mos. 24 mos.	18 mos. 24 mos. 36 mos.	24 mos. 36 mos. 48 mos.	36 mos. 42 mos. 48 mos.
DRILLS ATTENDED IN GRADE#	48 24 12	27 16 8	27 16 13	45 27 18	54 32 20	72 42 32	108 64 38
TOTAL TRAINING DUTY IN GRADE#	24 OR 48 12 NON-DRILLING	14 days 14 days None	14 days 14 days None	14 days 14 days 14 days	14 days 28 days 14 days	28 days 42 days 28 days	42 days 42 days 28 days
PERFORMANCE TESTS				Specific ratings must complete applicable performance tests before taking examination.			
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 1316, must be completed for all advancements.					
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.					
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.					
AUTHORIZATION		District commandant or CNARESTRA					BuPers

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

#Active duty periods may be substituted for drills and training duty.

READING LIST

NAVY TRAINING COURSES

Gunner's Mate 3, Vol. 1, NavPers 10158–A
Gunner's Mate 3, Vol. 2, NavPers 10182
Gunner's Mate 3, Vol. 3, NavPers 10183
Basic Hand Tool Skills, NavPers 10085
Basic Hydraulics, NavPers 16193
Basic Machines, NavPers 10624
Blueprint Reading and Sketching, NavPers 10077–A
Basic Electricity, NavPers 10086

OTHER NAVY PUBLICATIONS

Naval Ordnance and Gunnery, Volume 1, NavPers 10797 (except chapters 12 and 13)
Ammunition Handling, NavPers 16194

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education Officer.[1] A partial list of those courses applicable to your rate follows:

Number	Title
MA 781 or CA 781	*Elementary Electricity*
MA 836 or CB 836	*Machine Shop II*
MA 779	*Blueprint Reading*
MA 769 or CA 769	*Mechanical Drawing*

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[1] "Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services and materials if the orders calling them to active duty specify a period of 120 days or more, regardless of the time specified in the active duty orders."

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GUNNER'S MATE 2

CHAPTER 1

REVIEW AND PREVIEW

A MAN WITH A PLAN

Anybody can open this book and start reading it. But the book isn't written for just anybody to just read. It's intended for a particular man with a particular plan, and it's intended for him to STUDY. If you're the man, it's intended for you. And you are the man if you're a GM3 working for promotion to GM2.

THE GUNNER'S MATE'S JOB

In the appendix at the end of this book are listed the advancement qualifications for all the Gunner's Mates rates. If you look them over (and this is a good time to do it) you'll get a good bird's-eye view of the GM rating in terms of what the GM is expected to KNOW, and what he is expected to be able to DO. The quals call these, respectively, EXAMINATION SUBJECTS and PRACTICAL FACTORS. To qualify for promotion, you must, among other things, pass a written examination in the examination subjects and show that you can perform the jobs listed as practical factors. But, for the moment, consider these qualification items as parts of the whole which, taken together, represent what the Gunner's Mate does and is expected to know as a naval technician.

From this "bird's-eye" view you can tell that the GM rating covers a considerable amount of ground. Now let's get a little closer to that ground, and look briefly at typical billets that Gunner's Mates may be assigned to.

The *Manual of Navy Enlisted Classifications* (NavPers 15105) divides the broad Gunner's Mate's territory into a number of typical billets or work assignments. The least specialized one is called Gunner's Mate, Basic, which is where most Gunner's Mates start. But you can specialize in hydraulic gear as an Ordnance Repairman, Hydraulic, or in any of several other classifications concerned with hydraulics. If opportunity and your own interest and ability happen to coincide on this, you can after special training become a Mobile Ordnance Service Unit Technician. You may be assigned as a Gunnery Maintenance Man on a type (or several types) of mount, including gun, A/S, or rocket mounts. Or you can specialize in turret maintenance and operation. It's also possible to specialize in small arms work and in demolitions, or in guided missile work (though probably this will eventually be the exclusive province of Guided Missilemen).

This brief survey gives you some idea of the kind of billet you may expect as a GM2. Your experience as a GM3 has probably already pointed you in the general direction of some area in which you'll become a specialist. But, regardless of where you specialize, you are required to master, at least in a general way, the whole broad technical field of the GM rating. This course will help you do that.

HOW THIS COURSE WILL HELP

You know, naturally, that studying this course, passing an examination on it, and satisfying practical factor requirements, isn't all that's necessary for your promotion. You must meet certain requirements as to ARI and GCT examination scores, length of naval service, service at sea, and time in grade; you must meet other requirements as to conduct and proficiency in rate; you must pass examinations in military factors; and you need the recommendation of your commanding officer. There may be other requirements too, depending on regulations at the time you are working toward promotion. (See your division officer for the current requirements.) But the fact is that your TECHNICAL qualifications, apart from military qualifications and the other requirements mentioned, play a major part in qualifying you for promotion. So it's worth your while to dig in and work at them.

This course book is intended to help you in satisfying those technical qualifications for promotion to GM2. It is unlike many textbooks and other specialized or technical books which are designed around a field of knowledge, or a single process or skill, or a class of equipment, or even a particular mark and mod of equipment. This book is designed to meet YOUR needs. It is built around the qualifications that you must satisfy for promotion to GM2. It covers all the examination subjects. Naturally, no book can prepare you for practical factors in the sense that it can actually take the place of experience in doing the work, but this book, so far as possible, does prepare you for practical factors by teaching principles and relationships, by describing equipment, by explaining its functioning, and by providing background information.

Supplementary Sources

Although this book covers all the qualifications, not everything you need for promotion can be found between its covers. We've already mentioned the skills that just can't be put into a book. Besides that, you must supplement this book with study of equipment, of publications and films on equipment, and of BASIC COURSES. If you're lucky, you may also have the advantage of training at a Gunner's Mate's School.

For the moment, let's concentrate on what you can do on your own, even if you don't happen to be on a school quota while you're working for this promotion.

For one thing, there's the equipment. The Gunner's Mate can't function as a Gunner's Mate without the weapons and ammunition he is supposed to work with. Working with the equipment gives you an opportunity to learn about it, and you will do well to make the most of the opportunity. What's more, most division and gunnery officers will, if you show real interest and aptitude, cooperate by permitting rotation of assignments within the gunnery department every so often, to the extent that ship organization and workload permit. This, of course, is something that must be worked out informally through your leading Gunner's Mate and gunnery officer. But it will pay to improve your chances. Take full advantage of all drills and exercises—and even of casualties! The better you get to know the gear, and the more types of equipment that you know, the better will be your prospects, even if you wind up by becoming a specialist.

Yet no ship has aboard all the kinds of weapons and ammunition that a Gunner's Mate is supposed to know about. And that's where this course and the other sources of information we're discussing here prove most valuable. If you're a big-ship sailor, how else can you learn about A/S weapons? If you're a tin-can sailor, where else can you get what you need about demolitions? And so on. That's where this course is valuable.

But even this course doesn't, as we've already said, have everything. If you're assigned a billet in which you have responsibility for some of the gear described here, you'll find that much is omitted. It has to be. This book is no encyclopedia. But it will steer you to the books that are—the OP's and OD's issued by the Navy's Bureau of Ordnance (often referred to later in this book as BuOrd), the TM's and FM's issued for small-arms weapons by the Army, and others. Besides that, this book gives you introductory information that OP's and OD's and their like ordinarily take for granted. In addition, each chapter gives you an overview of the subject—a sort of guide map of it—that will help you to keep in focus not only the equipment itself but what you're expected to do with it and to it.

Then there are the basic courses. You probably know already that in addition to training courses like this one, the Navy also issues basic courses on such subjects as basic electricity, how to use blueprints, basic hydraulics, basic hand tools and how to use them, and the like. You'll find these listed in the reading list at the front of this book, and there are references to them here and there in the text of this course.

HOW TO USE THIS COURSE

This course textbook is intended to help you. The paragraphs preceding have indicated to some degree how it can. Yet you realize that this book—no book, in fact—can do everything. It cannot either think for you or eliminate the need for thought. But it will present the things you must know in the simplest and clearest way that the writer knows how to present them. The presentation includes BOTH text and illustrations, which must be studied together.

Don't look for sugar coating and decoration, either in the text or in the illustrations. As a GM3 working toward another stripe on your arm, you're considered a professional by the Navy, by your shipmates, by your officers, and by the writer of this book. You're studying technical subject matter using technical terminology. What's more, you're an advanced student, and no one will talk down to you. Nor are any "tricks" used to capture your interest. Every professional worth his salt is already interested in his profession and its subject matter.

That doesn't mean that anybody is trying to make things either dull or difficult. It does mean that in this course you are considered, and must consider yourself, a serious student. It means also that you want to learn so that you can advance in the rating you have selected, and that you are willing to put into your study the effort that you must give it in order to learn effectively.

Studying

You're a GM3, so we can assume that you already know how to study. But here are a few suggestions on how you can get the most out of this course.

The first suggestion is very important: SET ASIDE REGULAR HOURS FOR STUDY. We cannot tell you how many hours to set aside each week. Some men read faster and absorb information more quickly than others do. The important thing is to make a schedule you can stick to. Decide which nights you'll study, and how many hours, and when you'll begin. Then stick to it. If your schedule doesn't work, make a new one. But stay on schedule. You'll find yourself progressing a lot faster than if you study whenever the notion strikes you.

The second suggestion is: Before you begin your detailed study, spend an hour or two looking through the course as a whole. Get familiar with the chapter titles, and take a look at the section titles within each chapter. Look at the pictures. If a paragraph of the text catches your eye, skim through it. Go all the way to the end. Look at the quals again, and compare them with the text as you go along. After a while, you'll see which subjects you will need to concentrate on.

Now you can begin your actual study. When you begin a new chapter, read it through fairly fast. If you find the material interesting, read it just as you would a magazine article. Don't let the tough spots snag you—skip over them if they slow you down. You may want to make notes as you go along on things that require more detailed study. When you've finished this first quick reading, go back and read again, more slowly. Don't read it—study it. Don't take on a new section until you have mastered the preceding one.

Don't be afraid to take notes. The very act of writing something down makes it easier to remember, even if you never look at the note again. (But DON'T write in this textbook.)

By the way—don't take anything for granted. Some parts may seem absurdly easy. Maybe there really isn't anything new there for you. But don't jump to conclusions. Read everything. The review is worth while, and something new to you may crop up suddenly.

Using the Qualifications as an Aiming Point

Your target is the GM2 rating. But your aiming point must be the qualifications for advancement in rating. And, though this course book isn't organized like the quals, it's actually based on them. So you can see that it's important to keep the quals in your sights.

Appendix II reprints the qualifications as they are at the time of this book's printing. Changes occur from time to time, so it's a good idea to double-check with NavPers 18068, the official publication on quals, if you receive an older edition of this book. As we've already suggested, you should look over the quals in appendix II before you begin to study. And, when you take up each chapter, look at appendix III. This is like the table of contents at the front of this book, but instead of page numbers, the right-hand column identifies by number each qualification with which the chapter deals. The front part of each number gives the broad category into which the qual falls (for example, 201 means examination subject, operational), followed by the number of the qual in that category. This makes it easy to see just what qualifications each chapter can help you with. Note that one chapter generally covers more than one qualification, and that one qualification is often taken up in more than one chapter.

Using the Quizzes

The process of effective studying isn't confined to just reading—even concentrated reading and note-taking. As experienced teachers point out, you've got to EVALUATE—to take stock and see how effectively you've studied. One good way you can do this is by mentally reviewing what you've studied. But it's even better if you can get some kind of check from "outside." That's why you'll find a QUIZ at the end of each chapter.

All the quizzes in this course are of the short-answer type. This type of question was deliberately selected because it's so easy to use that you can get a quick selfcheck from it. That doesn't mean necessarily that it's always easy to pick the right answer. But this kind of quiz makes the self-checking quicker.

The right answer to every question in every quiz can be found in the text and illustrations in this book. (Don't forget those illustrations.) Remember that in multiple-choice questions you're supposed to pick out the ONE BEST answer, which means that you may sometimes have to throw out a near miss or even a partly correct alternate for the right answer. All the answers are given in the end of the book for your convenience in checking after you've taken the quiz.

Go through the quiz right after you've finished studying the chapter. Try to do it fast. Then check with the tabulated answers in the back. But put your answers on a separate sheet of paper, NOT in this book. If you write in this book, you spoil the quiz for the next man. In fact, if you're issued a copy with the answers written in, you'll be benefiting yourself if you erase them before you start to study.

Be honest with yourself when you take the quizzes, because they are intended ONLY as self-checking devices. Nobody's going to watch you or make any record of how well or badly you do. The quiz questions are selected only to cover some high spots. You can tell quite easily that none of the quizzes cover EVERY point in the chapter. They are really only a spot-check device. Therefore even ONE wrong answer is a big bright red danger signal. Don't just look up the one paragraph or figure in the chapter that contains the right answer. Go over the WHOLE chapter. You'll find that it's worth it.

Using References from the Reading List

The reading list at the head of this chapter includes basic Navy courses and USAFI course materials. Your I&E officer will give you the dope on USAFI. References in the chapters of this course will indicate when to refer to basic Navy training courses. And don't be afraid to go over the GM3 course book whenever it's mentioned as a reference and whenever you find you need brushing up on elementary stuff.

Other References

The most frequent references in this course are to OP's and OD's by BuOrd. These you can borrow from your gunnery department library. Most OP's and OD's are concerned with specific marks and mods of equipment, but some are about general subjects like battery alignment, and others are guides to types of equipment like ammunition and gun mounts. All are identified by number, and are listed in the Index to Ordnance Publications issued by BuOrd as OP 0. This has both a numerical listing which indicates for each publication the exact title, date, security classification, and status, and an alphabetical section which will show you what ordnance publications are issued for any given ordnance or gunnery subject, or for any mark and mod of equipment except obsolete material.

OP 0 also lists Army publications that you'll need—particularly on small arms. The Army has its own publication indexes (not usually available aboard Navy ships and stations), but except in unusual instances you'll find all you need in OP 0.

The Bureau of Ordnance also issues NavOrd Instructions not listed in OP 0, and there are other publications, generally classified, issued by BuOrd and other Navy agencies, that you may have occasion to use. You're not likely to need them in connection with this course; if your work requires that you use them, your division officer or leading PO will make them available.

Summary

We can summarize this section briefly this way:

1. For examination subjects—
    a. Use this manual as your main source of information.

    b. Pick up electrical, mechanical, and blueprint reading fundamentals, as required, from other basic manuals.
2. For practical factors—
    a. Study the applicable sections of this manual.
    b. Get specific information on gear from OP's and OD's and from your senior PO's.
    c. Practice on your gear and get to know it.
    d. Take full advantage of all training and drill periods to work with gun and magazine crews.

YOU AS A TEACHER

As a GM2 you will most likely not only be a learner but a teacher too. This is a function that is not peculiar to your rating as a Gunner's Mate, or to your second-class rate. All petty officers, of whatever rating, must know how to teach. The *General Training Course for Petty Officers* takes up in some detail the role of the petty officer as a teacher.

The GTC for PO's puts most of its emphasis on the First-class and Chief as teachers. Actually, you are likely to find such work coming your way too, not so much in formal classroom situations in schools ashore as in informal, practical work afloat. You have a teaching-learning situation whenever you're working with others in a drill or maintenance operation, as well as in more formal types of classes with demonstrations, lectures, films, and so on. The advantages to you of the drill and other crew operations, as in maintenance work carried on by a working party, are that groups are relatively small so that learning is more efficient, and that you're likely to learn more yourself.

There's scarcely a better way to learn something than to teach it. From the point of view of your technical improvement you're lucky if you have teaching assignments handed to you—whether small, informal ones, or actual classes—because you're likely to learn a good deal more than you teach.

We won't go into detail here on how to teach. See your *General Training Course for Petty Officers,* NavPers 10055, and the *Manual for Navy Instructors,* NavPers 16103B.

SAFETY

Along with your other increased responsibilities as a GM2 goes an increased responsibility for safety. Safety can't merely be called a part of your job; it's a part of every part of your job, from firing a mount to lubricating it to maintaining the flow of ammunition to it.

In general, you're responsible for the aspects of your job that have to do with safety. You learn them along with your job, because they're part of it.

We can't in this book give you all these details, but there are two things we can do. One is to call your attention to sources of safety information that you should be familiar with. The other is to take up some special aspects of safety that are a special concern of Gunner's Mates in most work assignments.

References on Safety

Safety is so much a part of the Gunner's Mate's job that regulations about it began to appear in print before they were thought necessary for other kinds of work on naval ships. You'll still find regulations about safety in gunnery in *Navy Regulations,* and it's worth looking them up there, especially if you're working in a bag-type gun turret.

A much more recent collection of safety regulations appears in a publication issued by the Chief of Naval Operations under the title *"United States Navy Safety Precautions,"* OPNAV 34P1. This covers the field of safety in all shipboard and shore activities that naval personnel are likely to participate in, including the matter of "industrial" safety. The chapter having to do with gunnery department operations is the one of most value to you.

There are several OP's on safety. (These are in addition to the safety material that you'll find in EVERY OP on equipment.) Three important ones on ammunition are OP 4, "*Ammunition Instructions for Naval Service Afloat,*" OP 5, "*Ammunition Ashore,*" and OP 1120, "*Care of Ammunition at Advanced Bases.*" Another is OP 1591, "*Clearing of Live Ammunition From Guns,*" which really is about dealing with ammunition under certain conditions in gun mounts. We'll go into this in a later section in this chapter. And OP 1014, "*Ordnance Safety Precautions, Their Origin and Necessity,*" will give you some gory but fascinating background on how many of these safety precautions began.

Then there is OP 1411, "*Safety in Combat Demolition Installation and Blasting for Underwater Demolition Teams,*" which is a specialized treatise in itself. Chapter 2 of this course gives you what you need in this field of demolitions, but you may want to study further in it, in which case OP 1411 is for you.

Eventually OP 2150, "*Ordnance Safety, Operation, and Maintenance,*" will cover this whole field in a special unified publication. This one is still in preparation; look for it and use it when it appears in print. In the meantime, you will find appendix A on safety precautions in the officer's text "*Naval Ordnance and Gunnery*" volume 1 (NavPers 10797) a useful general study reference.

And, lastly, don't forget to review your GM3 course to supplement this one in the field of safety.

Foul Bores and Flarebacks

In this and succeeding subsections we'll take up some specific safety matters that require special emphasis. They include foul bores and flarebacks; and misfire, hangfire, and cook-off procedures.

Let's start with foul bores and flarebacks. These terms apply differently, depending on whether you're talking about big turret guns or small arms.

When you're concerned with small arms, a foul bore is a dirty bore. A fouled small-arms bore can be fouled with anything from powder residue to mud and dirt (or an old cleaning patch).

Don't get the idea that this book advocates firing small-arms weapons with powder-fouled bores, but actually the presence of a small amount of powder fouling, though it has a bad long-term effect on bore life, is not likely to make the weapon unsafe to fire. The real dangers arise when the bore is fouled with something substantial like a cleaning patch, or a piece of cleaning hardware, or is plugged by mud or sand. If you're an armorer, you must inspect the bores of the weapons you issue to landing parties and others to be sure there aren't any obstructions in them. Even though a rifle or carbine isn't likely to pick up mud and sand on board ship, bores fouled by cleaning materials are a real hazard. (Landing party personnel should be warned about the hazards of mud and sand in gun bores.) You can see in figure 1–1 the effect on an M1 rifle of firing it with a solid obstruction in the bore. No photograph is available of the effect on the man who fired the weapon, but you can use your imagination.

Incidentally, in figure 1–1 the effect of the obstruction

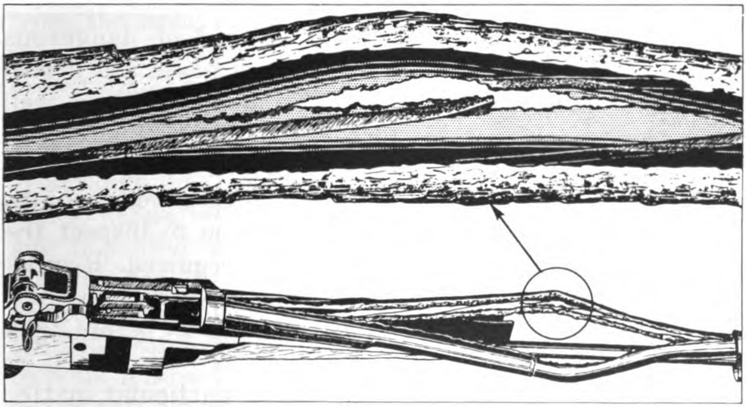


Figure 1–1.—Caliber .30 rifle M1 barrel damage caused by firing with obstruction in bore. (Upper view is an enlargement.)

was increased by the fact that the metal structure had been previously weakened. You can see why chapter 13 lays so much emphasis on weapon inspection.

Flareback (more often called BLOWBACK) in small-arms weapons refers to leakage of high-pressure propellent gas from the breech when the weapon is fired. This is caused by excessive wear or improper manufacture, resulting in excessive clearances (including excessive headspace) through which gas can leak. This can be dangerous to the user of the weapon. See chapter 13 for information on how to prevent it.

In larger naval guns, and particularly in bag-type guns (though this can happen in case guns too) the term "foul bore" refers to a gun bore fouled by GAS or by bits of smoldering powder bag fabric in the chamber. The gas is unburned or partly burned fumes from the propellant that remain in the bore after a round has been fired. The main purpose of the gas ejector in enclosed mounts is to blast this gaseous residue out of the bore. The gas is very easily ignited, or may even ignite spontaneously when mixed with atmospheric air. As you know, it takes very little to get a mixture of combustible gas and air to explode. It's this explosion that in connection with naval guns is called a FLAREBACK.

Though gas ejectors normally get rid of dangerous gases in the bore within seconds, such gases are a real hazard in enclosed mounts because they are toxic as well as explosive. If gas ejectors are faulty or ineffective, firing must be slowed to avoid accumulation of such gases, and to permit gas to drift out of the bore between rounds. If you're the gun captain, it's up to you to inspect the bore and give the BORE CLEAR signal as required. Regulations provide also that fired cartridge cases must be permitted to ventilate for at least ten minutes before they are sent below for stowage.

But foul bores and flarebacks are a particular matter of concern in bag-type turrets. Detailed regulations prohibit opening tanks or exposing powder within certain distances of open breeches before the bore clear signal, and prescribe maintenance of flametight integrity, sponging after each round, inspection of the chamber for bits of burning or smoldering powder bag, and safe practices in gun compartments, magazines, and hoist operation.

In any case, if you're in an enclosed mount or in a turret, be sure you know the gas ejector mechanism so that you can operate it manually if necessary, and that you know and practice the safety precautions prescribed for the installation.

Misfires, Hangfires, and Cook-offs

You are already acquainted with these terms and what they mean. You also know in general what to do when you have misfires, hangfires, or cook-offs. Or do you? Let's go over it.

You have a hangfire or a misfire when an unsuccessful attempt has been made to fire a gun (or rocket). Regulations prescribe that in peacetime or training, after the last unsuccessful attempt to fire, the weapon must be positioned in a safe direction (you can NOT depend on a firing stop mechanism in this case), personnel must be cleared from the area, and there must be a waiting period (30 minutes). Only after this waiting period may the misfired round be removed.

Sometimes this procedure can't be followed because even in practice operations a 30-minute wait may be hard to arrange, and most misfires or hangfires (except those due to defective firing mechanisms) occur after the weapon has fired a number of rounds and is already hot. Waiting for 30 minutes raises a strong possibility that the round sitting in the hot weapon will go off because of the heat—and nobody can tell exactly when it will go off. In tests, a 5-inch round has cooked off as much as an hour and a half after being loaded. On the other hand, a 20-mm or caliber .50 round can cook off in less than one second.

There is the additional complication that it isn't just the propelling charge that can cook off, though this, because of the factor of unpredictability, is bad enough. It is also possible for the bursting charge to cook off. This can rupture the gun barrel or launcher, and rip apart the breech.

In determining what to do in any specific case of misfire, the mount captain or other responsible crewman must use a considerable amount of judgment under very tense conditions. It's most important to know in advance the cook-off characteristics of the weapon. For guns, this information is summarized in OP 1591, and of course you'll also find it in the newer OP's. (For rocket and A/S mounts, conditions vary so much from one type of mount to another that the OP is the best guide to what to do during a misfire or hangfire. Or see chapter 12 in this course for a digest-type treatment of these.) You can use the following general rules as guides in your thinking, but they are NOT a substitute for knowing your gun mount and what it will do, and knowing what circumstances (number of rounds fired, rate of fire, incidence of misfires or other malfunctions) immediately preceded the misfire or hangfire you are dealing with.

1. *Cold guns.* If there is a misfire on the very first round in a cold gun, you can use the standard misfire procedure without worrying about cook-offs. This is true even in the tropics, and even if the metal parts of the gun feel warm to the touch because of exposure to the sun. Of course, under these conditions a gun will heat up somewhat faster when fired, but if it hasn't been fired for several hours, a gun is "cold" even in the tropics. It's likely that a misfire under such conditions is caused by firing system troubles rather than defective ammunition; go over the firing system carefully before loading another round. A "cold gun" has been defined as one that has fired fewer than 12 rounds in the past

hour, and not more than 50 continuously before that.

2. *Hot guns.* Actually, it isn't possible to lay out one procedure for cold guns and another for hot. A great deal depends on the type of gun and how hot it is. This last in turn depends chiefly on how many rounds have been fired and the rate of fire. We'll outline the possibilities below:
   a. *20-mm.* If a hot 20-mm gun misfires or jams with a live round in the chamber, standard peacetime procedure is to position the gun on a safe bearing, let all personnel clear the area, and let it cool for 30 minutes. If the magazine is easily removable, take it off. Also take off the empty case bag. While it's cooling, the barrel may be sprayed with water. After this period, cock the gun and let the ejected round fall into a container of water. If the round separates, use an ejector tool through the muzzle to force the projectile out.
   b. *40-mm.* The possibility of a cook-off in a 40-mm gun with properly functioning water cooling system is remote. On air-cooled guns, or if there's no water in the water jacket, be prepared for cook-off if a round misfires or jams in the chamber after 60 rounds or more have been fired. The peacetime routine is to position the gun on a safe bearing, elevate it somewhat, and run water into it from a hose. After 30 minutes, clear the gun. Remove ammunition in the loader and on the rammer tray. Then open the breech. If the round separates, push the ejector tool through the bore from the muzzle. The round should go into a water-filled container or overboard without delay.
   c. *3-in. and 5-in. guns.* If there is an apparent misfire or jam with a round in the hot gun chamber, first train the gun on a safe bearing.

Then check to see that all loading system components, firing switches, and relays are in their proper positions, the breechblock is fully closed, and that the firing circuits are energized. It's more likely that these will malfunction than that present-day electric primers will. You have about ten minutes to do this troubleshooting before there's any serious danger of a cook-off. Also attempt percussion fire. If none of these expedients work, the next step (under peacetime conditions) is, after one minute of waiting after the last attempt to fire, to elevate the gun to about 15° to 30°, train on a safe bearing, and with a hose fill the bore with water. Also spray the outside of the barrel. After a sufficient time (30 minutes has been recommended), it is safe to drain the water, open the breech, and clear the gun.

If the case extracts but not the projectile when the breech is unlocked and opened, it will be necessary to use a short case. For the method of doing this, see the OP on the gun. (Later in this course you'll find instructions for firing a short case in 3″/50 mounts; in 5″/38 mounts the procedure is very similar to firing service ammunition.)

Clearing the gun by using a short case is also permissible where the breech has failed to close completely and there is therefore no possibility of a hangfire.

Under combat conditions, a failure to fire under these circumstances may, at the option of the commanding officer, be dealt with differently. Under these circumstances, one minute after the last attempt to fire, but not more than ten minutes after the ammunition was rammed, the breech may be opened and the round removed. The gun may be cleared by using a short case if necessary. If the gun can't be cleared within ten minutes after ramming, then the water cooling procedure described above should be used. But remember that the procedure described in this paragraph is for combat conditions only, and then ONLY if the commanding officer orders it.

Rocket Safety

You've already had an introduction to rockets and their safety characteristics, so what we have to say here about them is chiefly review and summary.

Don't try to treat rocket ammunition like gun ammunition, or rocket launchers like gun mounts. There are some fundamental differences. Rocket launchers have danger areas BOTH behind and in front. Rocket motors are far more exposed to hazards, and rather more sensitive into the bargain, than gun ammunition propelling charges.

Each type of rocket launcher and each type of rocket ammunition has its own special safety rules, which you MUST learn if you are stationed on a rocket mount. But here are ten general safety ideas that have wide application and that you are responsible for knowing:

1. Don't stand (and don't let anyone else stand) behind a rocket launcher that is being loaded and fired; that nozzle blast is HOT.
2. When you load rockets, wear long trousers and long, buttoned sleeves. (This is required uniform for most gunnery operations, anyway.)
3. Maintain and operate the firing system in strict accordance with the BuOrd rules for that mark and mod of launcher. Always keep the firing circuit open until the time of firing. It should be open when loading the launcher, during misfire procedure, and at any time when men are in the danger area of the launcher.
4. Launchers should be kept ready-loaded only when required. Loaded launchers should be, so far as possible, protected from direct sunlight. Keep all extra rockets at a safe distance from the launcher.
5. Know and observe the rules regarding safe firing temperatures.

6. NEVER remove the ballistite grain from the rocket motor.
7. Never try to fire a rocket that has a loosened closure disc; dispose of the complete round as directed by your gunnery officer.
8. If a rocket misfires, clear the area and keep it clear for at least 10 minutes (unless otherwise directed by the CO). Then replace the fuze safety wire and dump the misfired round overboard. See also chapter 12 for further details on misfires on rocket launchers and A/S weapons.
9. Never expose rockets to any POSSIBLE sources of accidental sparks or flames; they ignite fast. Keep the short-circuiting tabs on the firing contacts till the last possible moment.
10. If you are working at an advanced base, or anywhere else under handicaps, do everything possible to give the rockets stowage in an area where the temperatures will lie within the safe firing range specified on the motor.

REVIEW

In this chapter we began with the nature of the job the GM2 is expected to be able to handle, and what he has to know in order to handle it. We went on to explain how you can use this book to help you earn a promotion to GM2, and indicated sources to which you should look for supplementary information that doesn't appear here. And we discussed methods of studying, with some emphasis on how to read each chapter and how to check on your studying by use of the quiz at the end of it.

The latter part of this chapter was devoted to safety in general and to several aspects of it—foul bores, flarebacks, misfires, hangfires, and cook-offs—that are of special interest to the GM2 who is working on gun mounts. And we concluded with a brief review of safety on rocket launchers.

PREVIEW

Now you're ready to start studying the main body of the course. There are fifteen chapters following this one, but they break up naturally into larger groups. You may find it advantageous to study these groups together.

Following this chapter is a chapter on explosives and demolitions, followed by one on the closely related subject of ammunition. Much of the information on explosives generally in chapter 2 is also basic to ammunition. You'll find the demolitions material particularly useful if you're a Gunner's Mate in the Seabees.

Chapters 4 and 5 are a closely related pair on hydraulics and hydrostatics. The first concentrates on the principles of behavior of liquids (though some elementary hydraulic devices are also discussed). The second is concerned with the mechanisms in ordnance gear that use hydraulic and hydrostatic principles.

Chapters 6 and 7 are also a closely linked pair, and are related to each other much as chapters 4 and 5 are. Chapter 6 is principally concerned with the fundamentals of fire control, while chapter 7 takes up fire-control mechanisms and instruments that you're likely to encounter as a GM2.

Chapter 8 can be considered in two ways. It's a complete review in itself of naval gun mounts from 20-mm to 5-in. and therefore serves as a general introduction to what is usually considered the Gunner's Mate's principal stock in trade. It also serves as a general introduction to the three chapters following—chapter 9 on breech mechanisms, chapter 10 on firing systems, and chapter 11 on recoil and counterrecoil systems. And within this group of four chapters (8 through 11), chapters 9 and 10 can be studied almost as one, just as it is possible to study breech mechanisms and firing mechanisms together. The reason that they weren't written as one chapter is that chapter 10 takes up firing SYSTEMS, and does not limit itself to the firing components that are physically part of a gun's breech mechanism.

Chapter 12 is more or less a "solitaire." It's complete in itself, and offers, as chapter 8 does for gun mounts, an overview of the rocket launchers and A/S weapons that the GM2 qualifications are principally concerned with.

Chapters 13 and 14 are a pair that take up what an armorer or small-arms expert should know. It also has useful information on landing party equipment, because that's a subject closely allied to small arms.

Lastly, chapters 15 and 16 are also a pair. Chapter 15 lumps into one sequence of pages the general maintenance information that a GM2 should have in addition to what he learned as a GM3. Of course, chapter 15 is no substitute for the regular sources of information on specific equipments, though it can give you general information on certain subjects like mount power drives. Chapter 16 delves much more deeply into an area of maintenance vital to your ship's efficiency as a fighter—battery alignment. The advancement qualifications specify boresighting and tramming as aspects of battery alignment that the GM2 is especially concerned with.

QUIZ

In each of the following multiple-choice questions, select the ONE BEST answer. DO NOT write in this book, or you'll spoil it for the next man. It's a good idea to get a separate piece of paper, write on it a column of numbers corresponding to the questions, and opposite the number of each question write the letter of your chosen answer. Don't refer to the text or illustrations of the chapter while taking the quiz, except where the question text specifically suggests that you do so. After you've finished all the questions (which are always short-answer type), check the right answers in the back of the book. If you have even ONE wrong, review closely the WHOLE chapter, though with special emphasis on the subject you missed up in. Remember, as the preceding chapter has stated, that these quizzes are only a spot check.

1. Which one of the following is NOT a factor that affects your chances for promotion to GM2?
   a. Your score on the ARI or GCT examinations.
   b. Your ability to perform certain tasks specified in advancement qualifications.
   c. Your score on the examination covering military subjects.
   d. Your score on the chapter quizzes in this course.
2. This chapter doesn't take up methods of training others because
   a. Gunner's Mates have no responsibility in training.
   b. only CPO's have training responsibilities.
   c. military qualifications cover training requirements.
   d. they are discussed later in this book.
3. For the most information on a specific ordnance equipment, the best source usually is the
   a. OP or OD on the equipment.
   b. basic Navy training course on the equipment.
   c. appropriate chapter in this course book.
   d. Navy training film on the equipment.
4. The main purpose of this quiz and the other chapter quizzes in this book is to
   a. provide a thorough review of the content of the chapter.
   b. provide a source to be used by the Navy in making up promotional examinations.
   c. furnish a quick spot check on how well the student has mastered the chapter.
   d. give the slow student an opportunity for extra study as a substitute for experience.

5. In naval guns in enclosed mounts, the term "foul bore" commonly refers to
   a. powder fouling in the bore.
   b. residual gas or burning embers in the bore after the gun has fired.
   c. faulty functioning of the gas ejector.
   d. blowback of powder gas around the breech mechanism from the bore and chamber.
6. If you have a misfire in a hot 20-mm gun, the presently recommended normal procedure is to position the gun on a safe bearing,
   a. wait 30 minutes, then eject the misfired round.
   b. remove the barrel, and dump it into water at once.
   c. eject the round before it has a chance to cook off, and heave it overboard.
   d. cock the gun and attempt to fire a second time.
7. The ballistite grain may be removed from a rocket motor
   a. to clear a misfire.
   b. if the rocket head is defective.
   c. if it has been overheated.
   d. never.

CHAPTER 2

EXPLOSIVES AND DEMOLITIONS

INTRODUCTION

In this chapter we shall take up the "raw material" of ammunition—explosives. In the first part of the chapter we shall study briefly the main characteristics of explosives. Then we'll take up in some detail the explosives used for various purposes in the Navy. Finally we'll study how explosives are used in demolitions. We'll discuss ammunition elsewhere in this course.

EXPLOSIONS AND EXPLOSIVES

Logically, we should start with the question: "What is an explosive?" But to answer that question, we must first ask another: "What is an explosion?"

As OP 4, *Ammunition—Instructions for the Naval Service,* wisely observes, "The term explosion is very broadly used to define a bursting with great violence and loud noise, thus covering many occurrences resulting from the action of other substances than those known as explosives." According to this broad meaning of the word, you can just inflate a paper bag, smack it with your fist, and have an "explosion." On a larger scale, you can tie down the safety valve on a locomotive, fire it up, and let the steam burst the boiler.

From the point of view of military usefulness, however, this broad nontechnical definition of an explosion is not very helpful. In this book, we mean by an explosion what happens when a bomb detonates, when a gun fires, or even when a Fourth-of-July firecracker goes off. All these true explosions have certain characteristics in common that bursting bags, boilers, and similar disturbances haven't got. These characteristics are—

1. Production of large quantities of gas
2. And large quantities of heat
3. Within a very short time.

The result is a drastic and sudden increase of pressure, "manifesting itself," as OP 4 rather modestly puts it, "in the disruptive phenomena accompanying an explosion."

A chemical explosive (as distinct from the atomic kind) produces this effect through extremely rapid decomposition (breaking up) and oxidation (burning). Modern explosives are based on chemical compounds (usually containing nitrogen) which can reliably be induced to do this. Nitrogen, which makes up about 80 percent of the air you breathe, is itself fortunately not an explosive. It is not even considered very active chemically. But it does combine with other chemical elements to form more or less unstable chemical compounds, some of which cause quite a disturbance when they break up. That's why you see NITRO (for nitrogen) in the chemical names of most modern explosives—NITROglycerin (used in dynamite), NITROstarch, NITROcotton (a component of smokeless powder), triNITROphenol (picric acid), triNITROtoluene (more briefly called TNT), and so on.

The atomic bomb doesn't fit into this category. The explosives you'll encounter depend on CHEMICAL reactions; the atomic bomb explosion is based on reactions within and between atomic centers or NUCLEI. There are more impressive factors involved in atomic explosions than in the chemical variety; unfortunately, interesting though they are, they cannot be discussed further in this book.

GENERAL CHARACTERISTICS OF EXPLOSIVES

Each explosive has its own set of characteristics, and experts have elaborated on these characteristics in great detail. In this course, we can boil down these characteristics to two main types—RATE OF BURNING, and SENSI-

TIVITY. Before we study individual explosives, we'll define a few terms often used in connection with explosives, and discuss the behavior of explosives in general with respect to these two main types of characteristics.

Burning Rate

The most important characteristic of an explosive is how fast it burns. Although the word burning is applied to explosions, the process is quite different from burning of the usual sort. Ordinary burning, such as the flame of a match, can only take place in air, or, more exactly, in the presence of oxygen which makes up 20 percent of air. Explosives and propellants are made so that the oxygen necessary for the burning is right in the explosive itself in a very concentrated form. For this reason, although water will put out a fire, it will not stop an explosion. Weapons such as torpedoes will explode in deep water as effectively as in air.

A HIGH EXPLOSIVE is one whose burning is so rapid that it's called HIGH-ORDER explosion, or DETONATION. There are also LOW EXPLOSIVES, whose burning (LOW-ORDER explosion, or DEFLAGRATION) is at a much slower rate.

Don't let the term "low-order" fool you. Low-order explosion is by no means "slow" as compared to the burning of ordinary fuels. Under 36,000 pounds per square inch (psi) or so (a common pressure in a gun chamber), the propellant will burn in "low-order" at 56 to 60 inches per second. However, a high explosive like TNT detonates at about 7,600 yards per second, which is several times the velocity of any man-made projectile. Low-order explosion is slow only as compared to detonation.

Because a low explosive will burn and build up pressure slowly, it can deliver a powerful sustained push. As a gun propellant, it "follows through" all during the projectile's movement in the bore. (All of this takes only a fraction of a second, but it's "slow" compared to high-order detonation.) In rockets, it burns even longer. Hence a propellant must be a LOW explosive.

This low-explosive/high-explosive classification is not altogether hard-and-fast. A lot depends on the conditions under which the explosive is burning. For instance, the propellent powder that burns in a gun chamber under 36,000 psi at 50 to 60 inches per second will burn in the open air at only 0.05 inches per second—one-thousandth of its burning rate in a gun. If you grind the propellant up fine, you can even get it to detonate.

Or, to take a more extreme example, a mixture of gasoline and air in the cylinder of an automobile engine acts like a low explosive when first ignited, but can detonate like a high explosive when it's about half burned. (This detonation is the cause of "ping" or "knock" that people who sell high-test ethyl gasoline talk about so much.)

Conversely, you can get some high explosives to burn tranquilly by igniting them in the open air with a flame.

However, most military explosives, operating under normal conditions, don't vary in their characteristics like gasoline-air mixtures. Under service conditions, when used as they're supposed to be used, military explosives behave in the ways they're designed to behave. In this course we shall discuss them only in terms of service conditions. When you encounter high explosives, treat them like high explosives; they're not going to change their habits very much.

You know that detonation or "knock" in gasoline engines causes overheating and reduces efficiency. Detonation is essentially destructive; it can't be made to do useful work like turning a crankshaft in an engine or pushing a projectile in a gun. Put a high explosive in the cartridge case of your 5"/38, and all its energy will be expended in shattering the gun before the projectile has a chance to move.

But if you want to shatter, destroy, and scatter lethal fragments, you put HIGH explosive as a BURSTING CHARGE into the projectile, bomb, or torpedo that you're sending to the target. A high explosive detonates with a blast destructive because of its own effect and because of the high-velocity fragments it produces.

The shattering ability of a high explosive is known by an elegant French word: BRISANCE. Brisance hasn't much to do with the strength or power of an explosive, which is measured by the quantity of heat and gas given off. Its shattering ability depends more on rate of detonation. Oddly enough, the more brisant explosives are often weaker than their slower brethren. Fulminate of mercury, for instance, which is one of the most brisant explosives in the business, has, pound for pound, only one-fourth the energy of nitroglycerin (the active ingredient in dynamite).

Incidentally, explosives in general contain, pound for pound, less energy than common fuels. Coal has four times, and petroleum nearly eight times, the energy content of nitroglycerin. If you could get it to detonate, coal would make a far better bursting charge than an equal weight of TNT.

Sensitivity

·Explosives vary in sensitivity much the way people do. Some blow their tops rather easily; others only on considerable provocation. Some are more sensitive to a hot-foot; others have to be slapped around. Or, in other words, some explosives react to heat, others to sharp blows (though they often can withstand high pressures gradually and steadily applied). And some are easily detonated by either heat or shock.

Since modern warfare requires handling and storage of huge quantities of explosives, sensitivity is a quality of the greatest importance. As far as handling is concerned, the less sensitivity an explosive has, the better. Fortunately (from this point of view), some of the most powerful military explosives are also the least sensitive. In one experiment, an 1,800-pound pile-driving hammer was dropped 35 feet onto a depth charge casing containing TNT. The casing's sides were ruptured and deformed, but the TNT did not go off. That's no reason to go after the next TNT charge you see with a sledge hammer; but on the other hand you needn't worry, the next time you handle the stuff, that it will detonate if you give it so much as a nasty look.

However, if TNT and other explosives are so insensitive, how can you get them to explode when you want them to?

The answer is to use a small quantity of a more sensitive explosive to set off the insensitive main charge. In all modern explosive naval ammunition, and in most demolition setups, you begin with a very small amount of an explosive that is very sensitive to either heat or shock or both. You set off this INITIATING EXPLOSIVE either with the impact of a firing pin, or with the heat produced by an electric current in a small wire FILAMENT. The initiator in turn sets off the bursting charge directly, or (more often) sets off a high-explosive BOOSTER which in turn detonates the main charge.

High explosives can also be initiated by the INFLUENCE of another explosion at some distance, because of a shock wave transmitted through air, water, or the ground. From your point of view, detonation by influence (also called SYMPATHETIC DETONATION or COUNTERMINING) is ordinarily something to be prevented.

CLASSIFICATION OF EXPLOSIVES BY SERVICE USE

We can classify the uses to which explosives are put into four broad groups which we'll identify by the following headings:

1. Propellants
2. Bursters or disrupters
3. Initiators
4. Auxiliaries.

Few explosives are used in only one of these categories to the exclusion of others. So don't think of these as hard-and-fast groupings. But you will find them useful in associating explosives with their principal areas of use.

Now let's take up each of these broad classes in more detail.

Propellants

Propellants are all low explosives. Such an explosive functions by burning rather slowly (for an explosive) and producing a large quantity of hot gas over a relatively long period of time (long, that is, for an explosive). Low explosives are used as impulse charges for heaving depth charges and A/S projector charges, and for launching torpedoes (through tubes). They propel rockets. And, in the application probably best known to you, they propel projectiles through gun tubes. Examples of propellants are BLACK POWDER (used in impulse charges), BALLISTITE (for rockets), and SMOKELESS POWDER (for guns). Propellants must be relatively insensitive, so that it will be practical to store and ship them in the quantities in which they are used in modern ammunition.

Bursters or Disrupters

Bursters or disrupters are almost always high explosives which produce maximum blast effect, the maximum number of high-velocity fragments, or both. You find them in torpedo warheads, rocket heads, gun projectiles, depth charges, A/S projector charges, mines, and bombs. And they are the "business end" of the demolition setup.

Since its function is to produce the maximum damage to the target through blast force and the effects of fragments hurled in all directions (FRAGMENTATION), a bursting explosive must be a HIGH explosive with maximum power and the proper brisance. If its brisance is too low, the projectile casing may break into a few large but slow-moving and poorly distributed fragments. On the other hand, too high a brisance will break the projectile casing into finely divided fragments, not much more effective than so much dust.

Usually bursters or disrupters used in projectiles, rocket heads, torpedoes, mines, bombs, and depth charges are such high explosives as TNT, ammonium picrate, amatol, RDX (usually a component of another explosive), and tetryl. The high explosives most commonly associated with demolition work are TNT, amatol, tetryl, dynamite, blasting gelatin, and nitrostarch. RDX is used in demolition work in combination with other explosives, as are TNT, amatol, and tetryl.

Sometimes the maximum fragmentation effect is not wanted in a disrupter—for example, when the function of the disrupter is merely to break up a thin-walled projectile and scatter chemical or incendiary material. Then we use a low explosive, usually black powder. Similarly, we use black powder in demolition work where we don't want excessive fragment velocity, or reduction of fragments to too small a size. (Civilian quarrymen and coal miners may use black powder for exactly the same reason.)

Sensitivity is a primary factor in the usefulness of a high explosive as a burster or disrupter. Large quantities of ammunition containing bursting or disrupting charges have to be stored and handled. To be handled safely, these charges, like propellent explosives, must be relatively insensitive. However, there is an even more important reason why bursting and disrupting charges in gun projectiles must have low sensitivity. To begin with, a projectile must sustain the shock of being fired from a gun; a bursting charge that cannot survive the shock without detonating has no place in modern gunnery. Secondly, any projectile that hits anything (preferably the target) not only must explode if it contains a bursting charge, but must explode where it will do the most damage. When the target is armored, this means that the bursting charge must explode NOT when the projectile strikes, but AFTER THE PROJECTILE HAS PENETRATED. A burster that goes off before penetration is worthless. You can easily see why low sensitivity in an explosive used as a burster or disrupter is as important as its explosive power.

Initiators

Good propellants, bursters, and disrupters have in common one important feature—they're all relatively insensitive. We have already explained why they have to be. Because of this insensitivity, we must use small quantities of sensitive explosive to set off the propellant or burster.

To initiate the burning of a propellant, we use a PRIMER. This contains a sensitive explosive like mercury fulminate or lead azide, both of which are very sensitive to heat and shock. It's easy to see how one of these explosives plus some black powder in a PERCUSSION CAP, can produce a flame (upon percussion) to ignite a propellant. Or, to make it go off electrically, a small filament, when heated by the firing current, ignites a wisp of guncotton, which in turn sets off fulminate or azide.

To initiate the detonation of a high-explosive burster, we use a DETONATOR. This, too, contains lead azide or mercury fulminate, but because high explosives are more sensitive to shock than to flame, detonators contain also small amounts of tetryl or granular TNT (which is much more sensitive than the solid compound).

In ammunition, of course, you find all sorts of variations of these simple fundamental arrangements. (More about this in another chapter.) In demolition work, you will set up some of these arrangements yourself.

Auxiliaries

So far, so good. We have propellants for sending our projectiles on their way, burster charges for exploding them at the right time, and initiating components for igniting the propellants and detonating the bursters.

But this isn't all. Consider, for example, a Mk 9 depth charge. This contains a 190-pound TNT burster charge. The Mk 1 Mod 1 detonator for this depth charge contains only 65 grams (a little less than 2.3 ounces) of mercury fulminate. That's not very much. In fact, it's so little that you can't count on so small a detonator to set off

190 pounds of relatively insensitive TNT. On the other hand, you don't want to increase the size of the detonator. Detonating compounds like mercury fulminate are nervous stuff and extremely hazardous in any larger quantity; increasing the amount of such materials in explosive devices multiplies the dangers many times over.

That's why we need what we have here called AUXILIARIES. They make up the "middlemen" in the explosive train. In the Mk 9 depth charge this middleman is the Mk 6 Mod 4 BOOSTER, which contains 3 pounds of granular TNT. Because it's in the form of small particles tightly packed together, granular TNT is more sensitive than regular cast TNT—though it's not nearly so sensitive as detonating compound—and can always be set off by a small detonator (fig. 2–1). Where the burster charge is extremely large (as in large demolition (GP) bomb), you often find another link added in this chain reaction, with an AUXILIARY BOOSTER passing the explosion on to the main burster charge.

As you might expect, the same kind of train is used in propelling charges, and for the same reasons. Figure 2–2 shows how it works in a bag gun. The process begins with setting off the heat- and shock-sensitive primer. Here a small amount of black powder in the primer, ignited by the mercury fulminate (or lead azide), produces a long spit of flame which sets fire to the black-powder IGNITER.

In bag ammunition the black-powder igniter is in the

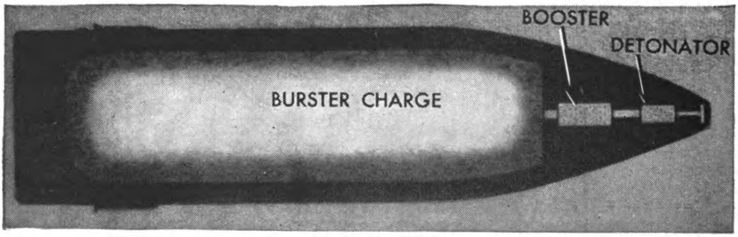


Figure 2–1.—Explosive train in an HC projectile.

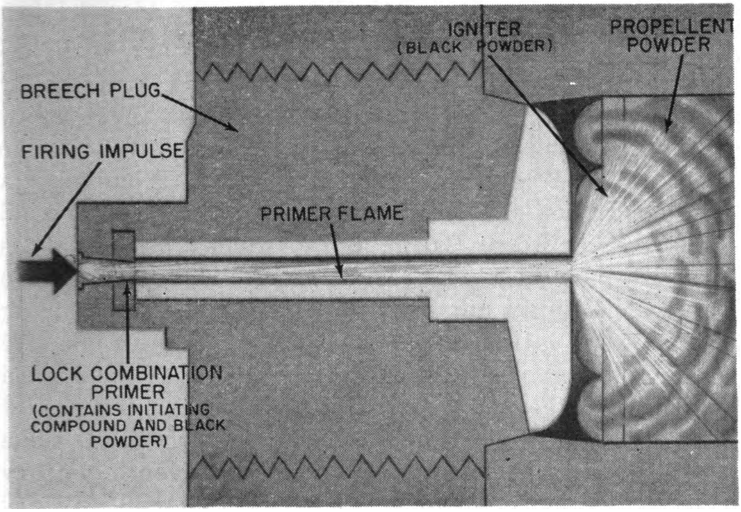


Figure 2–2.—Ignition train in a propelling charge (bag gun).

quilted red-dyed end; the figure indicates clearly why the bag must be loaded with this end aft. If the bag is loaded wrong end to, you're very likely to have misfires because the smokeless powder in the bag is not apt to take fire from the unassisted primer flame—even if the flame succeeds in igniting the bag fabric itself. The usual procedure with such misfires is to continue firing primers until the propelling charge ignites, since it's dangerous to attempt unloading because of the danger of hangfire.

In case-type propelling charges, as you will see in another chapter in this book, the igniter is in a perforated cylindrical stock secured to the middle of the base of the case so that it receives the flame from the primer and sets fire to the central part of the smokeless powder charge.

LOW EXPLOSIVES

Now let's go on to study specific explosives used in the U. S. naval service. We'll begin with low explosives.

Black Powder

BLACK POWDER is a good explosive to start with, because it was the earliest to be developed, and is still fairly common. Some historians believe that it was invented by the Chinese, and that its formula was transmitted via the Arabs to the Western World. A formula (though not a very good one) for black powder was recorded around 1250 by Friar Roger Bacon, and its earliest use in battles seems to have been at Crécy, France, in the fourteenth century. Within a hundred years, primitive cannon using black powder as a propellant were used also with decisive effect in naval warfare. Black powder was used as a bursting charge for projectiles and for early types of "torpedoes." (Nowadays we'd more likely call them mines.) Until the closing years of the nineteenth century black powder ("gunpowder") was the universal military explosive.

Black powder is a mixture of potassium or sodium nitrate, charcoal, and sulphur. In the very early days the usual proportions of the mixture made gunpowder relatively weak but extremely sensitive. The components, ground up practically to dust, were mixed by the gunner on the day that firing was to take place. The mixed powder was so fine that its dust around and upon the gun and gunner made gunnery more hazardous for the gunner than for the target. After a few years, fortunately, men handling black powder learned to mix it in advance, and to "corn" it—add water and form the mixture into lumps or grains.

Gunners noticed long ago that larger grained powder was more suitable for large guns. But it wasn't until the 1860's that Major Rodman of the United States Army actually conducted a scientific study of black powder as a propellant. He found that its burning speed could be regulated by varying the shape and size of powder grains, with the larger, slower burning grains best for larger guns.

To get the best burning characteristics, Rodman formed the powder into cylinders with axial holes through them. Since black powder is no longer used as a propellant in naval guns, you won't find it in this form any more, but the principle is applied in today's smokeless powder.

There are five sizes of black-powder grains currently used in our Navy. The largest size, 6-sided grains with rounded ends (spherohexagonal), is used as an impulse (propellent) charge in depth-charge K-guns and torpedo tubes. Cannon powder, the next size, is used in the ignition pads sewed on powder bags. There are three smaller sizes, used (either alone or in combination with another explosive) as burster charges for certain types of projectiles, in primers, and in fuze delay trains.

As explosives go, black powder is one of the most dangerous. It must always be handled with the greatest care. A few of its properties, and precautions that should be observed in handling it, are:

1. It possesses practically unlimited stability if stored in tight containers and kept dry. (Black powder, and assemblies containing it, should be regarded as unserviceable if they have become damp or wet.)
2. It deteriorates irregularly when moist.
3. It is not affected by moderately high temperatures.
4. It is highly inflammable and sensitive to shock, friction, and sparks.
5. If you can, avoid opening containers of black powder in the presence of other explosives or ammunition. The maximum limit that you can expose, in magazines or turrets, is 25 pounds.

Even with Rodman's improvements, black powder had many drawbacks. As a propellant, it was still inefficient because it burned too quickly, putting a heavy strain on the walls of the gun chamber and yet failing to maintain gas pressure for any great distance of projectile travel. That's why oldtime guns using black powder always had

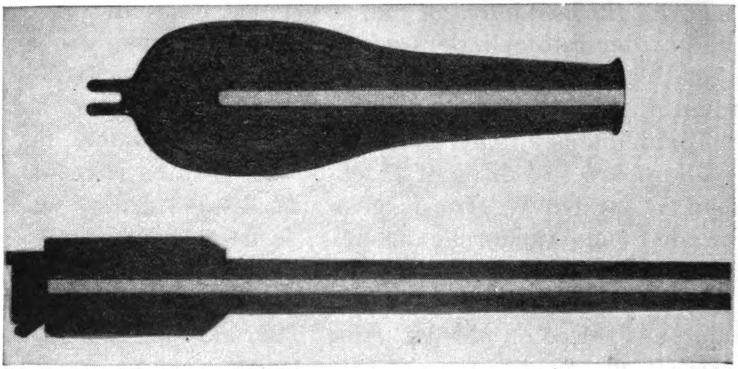


Figure 2–3.—The old look and the new in gun barrel profiles.

bulging breeches and short barrels. In modern guns, propellant gas pressure delivers an effective thrust over a much greater distance, and the propellant does not explode with a sudden shock that requires excessive extra thickness around the gun chamber. Figure 2–3 shows how the changed burning characteristics of propellants have changed the old bulging, brief barrel to a long, lean tube.

Black powder is still a useful explosive today—but not as a gun propellant. In the old days, because black powder did not burn completely, it fouled the gun with unburned carbon, and produced a brilliant flash, easily visible to the enemy at night, along with huge quantities of billowing black smoke—easy for the enemy to see, but difficult for the gunner to see through. (The irritating effect of black-powder fumes was relatively only a minor annoyance, but it made red eyes the distinguishing mark of a gunner in the old days.)

As a bursting charge, black powder was relatively weak. It was dangerous to store and transport because it was so sensitive to sparks, friction, and shock. And it deteriorated easily when wet—which is why the oldtime gunner was so much concerned with keeping his powder dry.

Smokeless Powder

The disadvantages of black powder were no secret, but it was not till early in the nineteenth century that chemists began to look for better explosives in a big way. They put together (and often disastrously blew apart) a number of substances much better adapted for various specific use in ordnance than black powder was. Many of the chemical explosives we use in the Navy today are products (though now much improved) of this era of chemical research. The smokeless powders used in the U. S. Navy are good examples of these.

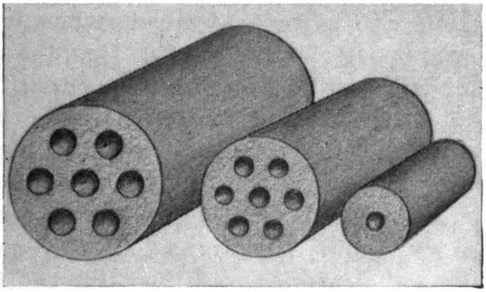


Figure 2–4.—Grains of smokeless powder.

There are two main types of smokeless powder now in use in the Navy. Both are generally similar in their physical form—cylindrical perforated grains, of assorted sizes much like Rodman's original black powder, with larger grains used in larger guns. The large-sized grains have seven holes; smaller grains (for guns smaller than 40-mm) have only one. (See fig. 2–4.)

Pyro Powder

PYRO POWDER, the earlier (and at this writing the more common) of these two types, is mainly composed of CELLULOSE (a plant fiber). In this country, we use highly purified cotton for its cellulose. (But other plant fibers—flax and even wood, for example—can be used.) In powder manufacture, the first step after purification is NITRATION—treating the cotton with a mixture of sulfuric and nitric acids. This treatment is what turns harmless cotton into an explosive compound that is variously called PYROCELLULOSE, PYRO, NITROCELLULOSE, or GUNCOTTON. Then machines beat the pyro to a pulp to break up the cotton fibers. It is further purified, and dried in big hydraulic presses which pump alcohol into it and mold it into large blocks. The blocks next go to "block breaker" machines to break them up. Then the pieces go into mixing machines which knead them.

At this stage there is added a solution of ether and alcohol containing DIPHENYLAMINE. This is a STABILIZER, whose function will become apparent when we discuss how pyro powder deteriorates. After this, the powder is again pressed into blocks, which are squeezed through a "macaroni" press that converts the blocks into long solid macaroni-like strands. (As you can guess, the main reason for all this breaking, mixing, purifying, molding, and so on, is to eliminate entirely the original fibrous structure of the cellulose.) Again, the stands are pressed into a block. Finally, the powder is forced, for the last time, through a die which squeezes it out or extrudes it as a perforated cord of circular cross section. The cord goes through a grain cutter which cuts it into grains of uniform length.

By now the powder looks pretty much as you see it in figure 2–4, but it is still soft and is called "green" (though it's actually ivory in color) because it contains too much of the ether and alcohol solvents. So it goes to "dry houses," where excess solvents are dried out—a 2- to 3-month process.

After drying, the powder is blended with other batches of similar powder to make up an INDEX. Samples from the index are made into charges and proof fired to check its performance. After the index has been formally accepted by the Navy, it is assigned an index number and is ready for issue to the Fleet.

Newly made pyro powder has a hard, horn-like finish, and varies in color from light ivory to a fairly dark brown. It tends to darken with age (though this is NOT necessarily a sign of deterioration). Old powder may be returned to the factory to be REWORKED. The powder may emerge from this process almost dead black—but again, this is no sign of deterioration, if the finish is still hard. Softness or mushiness of pyro powder is one (and a most serious) sign of deterioration.

Pyro powder is superior in almost every way to the black powder that it supplanted. Its relatively slow burning produces steady gas pressures that "follow through" on the projectile all the way through the gun bore, without the destructive initial shock that is inflicted by black powder. It's less sensitive to shock and flame and moisture (though, since it is, after all, an explosive, it must still be protected from them). It makes less smoke and flame, and has far less tendency to leave unburned residue fouling up the gun bore. But it does have a disadvantage that black powder hasn't: It doesn't keep quite as well when it's warm.

In another chapter we'll go into more detail about how and why this deterioration occurs, how it's detected, and what the Navy does to reduce it. For the moment, let's just say that even under unfavorable conditions, pyro powder stabilized with diphenylamine will last a long time, while under reasonably good conditions it will last for years.

SPCG or Cordite N

The second type of smokeless powder is SPCG, also called CORDITE N. This propellant is relatively new to the U. S. Navy. It differs in composition and color from pyro powder, which contains but one explosive component—pyrocotton—and is therefore termed SINGLE-BASED. SPCG is termed TRIPLE-BASE powder. It actually contains THREE main explosive components. These components are NITROGUANIDINE (55 percent), NITROCELLULOSE or pyrocotton (19 percent), and NITROGLYCERINE (18.7 percent), which, as you probably know, is the active agent in dynamite. The remaining 7.3 percent is the stabilizer, called CARBAMITE or ETHYL CENTRALITE.

Cordite in its original form was developed quite a long time ago. The British adopted it around 1888 and several foreign countries still use it. However, this old type of Cordite has the serious disadvantage of a high burning temperature, which causes excessive erosion of the gun bore and chamber. Cordite N (SPCG) avoids this drawback because its composition includes, as noted above, a relatively large proportion of nitroguanidine, a "cool-burning" explosive. This reduces the burning temperature to a value comparable to that of pyro powder.

SPCG is made in the same grain sizes and perforations as pyro powder, and ballistically gives similar performance. In general, SPCG is handled like and is governed by the same regulations as other smokeless powder, except for the routine tests made to ascertain its condition. SPCG is chalk-white and opaque when new, and yellows slightly with age. After prolonged deterioration has set in, SPCG darkens to brown and tends to scale off. However, SPCG deteriorates much more slowly than diphenylamine-stabilized powder.

As has already been indicated, we'll go into more detail about inspection and testing of smokeless powder in a later chapter. Let's go on now to take up the propellant used for rockets—BALLISTITE.

Ballistite

Ballistite is a double-based powder. It has two main components—nitroglycerin and nitrocellulose in approximately equal parts—plus traces of diphenylamine as a stabilizer.

Ballistite makes a superior rocket propellant. The maximum gas pressure in a rocket motor is about one-tenth that in a gun chamber. At such pressures single-based powders (like pyro) burn irregularly; ballistite burns smoothly at low pressures and yields a steady, reliable output of gas—which makes for smooth ballistic performance.

Ballistite as a rocket propellant is not a "powder" in physical form; in fact, the propelling charge for each rocket is cast as a single "grain" and is turned by a special lathe at the powder factory to the proper dimensions for assembly in the rocket motor. As you will learn in a later course in this series, the burning characteristics of ballistite (and its behavior as a propellant) are greatly affected by its shape.

The ballistite propelling charge of present-day rockets is very sensitive to high temperature—even more so than smokeless powder is. Rocket motors should therefore not be needlessly exposed to the direct rays of the sun or to any temperature in excess of that printed on the motor tube. If they have been exposed to excessive temperatures, they must not be fired until they have been allowed to return to a temperature within the safe firing limits. Otherwise the rocket may blow up on the launcher.

Rocket motors which have been exposed to excessive temperatures (in excess of the upper limit or less than the lower limit printed on the tube) should be kept within the safe firing limits for at least 6 hours before use. Even better, every effort should be made to keep rockets in ready service within the safe temperature firing limits at all times.

Under NO circumstances is the propellent grain to be removed from the motor of any rocket. Any rocket motors on hand in which the closure disc or disc have become loosened must not be fired. Dispose of them either by returning them to the ammunition depot, or by dumping into deep water.

HIGH EXPLOSIVES

And now we come to high explosives—the chemical compounds and mixtures that are, in general, used for destructive purposes. In this chapter we shall concentrate on those explosives that are actually used to make up burster charges for rockets, gun projectiles, aircraft bombs, and underwater ordnance. Explosives used for demolitions will not be taken up here, except for those actually used in the equipment discussed in the final section of this chapter. For further information on demolition explosives, see the NAVY TRAINING COURSE for *Gunner's Mate 1 & C*.

Prior to World War II, the Navy depended almost entirely on just two high explosives—TNT and Explosive D. By now there are considerably more, each with special advantages and uses. Some of these explosives are actually new explosive compounds; others are mixtures of explosives plus other agents.

The ideal military high explosive should, as required in each application, have the following qualities (which are not listed in order of importance, because the importance of each quality depends on the application):

1. It should have maximum power or explosive effect (which includes proper explosive characteristics for most effective fragmentation).
2. It should have maximum stability to withstand unfavorable storage conditions (heat, cold, moisture, and the like).
3. It should be easy to handle, cheap to manufacture in large quantity, and easy to load at maximum density.
4. It should produce proper fragmentation.
5. And it should be insensitive enough to withstand the—
    a. Shock of the propelling charge (if in a gun projectile).
    b. Impact of striking armor (if in an AP projectile of any kind).
    c. Impact of shell fragments and small-arms bullets (if in a demolition setup).
    d. Shocks of routine methods of transportation.

No explosive yet developed meets all of these requirements itself. So the Navy has a number of explosives for different purposes.

TNT and Related Explosives

Let's begin with TNT and those explosive mixtures based largely on TNT. The letters T-N-T stand for TRINITROTOLUENE. When pure, it's a white crystalline substance that melts at about 177° Fahrenheit—which is well below the boiling point of water. As an explosive, it works just as well when not absolutely pure, and is cheaper to manufacture, so you'll find it usually in impure form, which is light yellow to dirty brown in color, and has a lower melting point. TNT has the advantages (not shared by all other high explosives) of being relatively insensitive to heat, shock, and pressure, and of not combining with metals in contact with it to form sensitive explosive compounds. It does, however, combine with organic materials containing cellulose—wood or fabric, for example—to form such compounds.

TNT burster charges are usually made by pouring the melted TNT directly into the burster charge cavity of the ammunition, then letting it cool and harden. In this form it is not sensitive enough to be set off directly by a detonator, so we use a booster, usually of the more sensitive crystalline or granulated TNT.

TNT in any form is not insensitive enough to use in armor-piercing projectiles, but it's used widely in other gun projectiles, in depth charges, bombs, mines, torpedo war heads, rocket heads, demolition charges, boosters (in which it's granulated to increase sensitivity), and in demolition charges.

TNT is the main component of two explosives—AMATOL and TRITONAL—and a minor component of several others. Amatol is used mostly in aircraft bombs, and consists of a mixture of TNT and ammonium nitrate. Ammonium nitrate, though it is not often used as an explosive by itself, does function as one when mixed in this way. Since it is plentiful, cheap, and easily handled, it's good for "stretching" TNT in ammunition with exceptionally large bursters, like general-purpose (GP) or high-capacity aircraft bombs. It is also used in demolition charges. Both TNT and amatol are unfavorably affected by water or moisture, and amatol is HYGROSCOPIC (tends to absorb water).

Tritonal consists mostly of TNT, with about 20 percent aluminum powder added to increase heat and blast effect. It's used in GP bombs.

RDX and Related Explosives

RDX (also known as "cyclonite" and "hexogen") has a higher detonation velocity and is a great deal more powerful than TNT—and, inconveniently, it is a great deal more sensitive. Because of its sensitivity, its crystals (in pure form) must be coated with beeswax even to make it practical to handle. It is not used by itself as a military explosive. It must be mixed with other materials. It is the main component in compositions A, B, the three types of C, HBX, and Torpex, which we shall now take up in turn.

COMPOSITION A consists of RDX and a relatively large proportion (9 percent) of wax, which reduces its sensitivity so much that it can be used as a projectile filler in place of the insensitive but less powerful Explosive D (which we'll take up later). It can also be used in fragmentation projectiles.

COMPOSITION B is 60 percent RDX, nearly 40 percent TNT, and the remainder wax. The RDX adds power, the TNT (which can be poured in, thus adding to the density of filler) reduces sensitivity, and the resulting explosive can be used as a projectile (other than armor-piercing) rocket head burster, or fragmentation bomb burster.

COMPOSITION C is a plastic mixture of about 90 percent RDX and 10 percent oil. It remains plastic over a wide range of temperatures, and when used as a demolition explosive it can be molded around irregularly shaped objects or for use as a shaped charge. There are three varieties. Composition C–1, which is plastic between zero and 110° Fahrenheit, is obsolete. Composition C–2 and C–3 are basically similar, but remain plastic over a wider temperature range (minus 20° to plus 125°F). Composition C is more powerful an explosive than TNT, and has a higher velocity of detonation (which gives more destructive shattering effect).

HBX (or the more recent variety, HBX-1) is composed principally of Composition B and aluminum powder. It is the most recent in development of the Navy's high explosives. It is much more powerful than TNT, but has TNT's insensitivity to impact. HBX is used mostly in underwater ammunition.

TORPEX, which is based on the same materials as HBX, was developed during World War II and used as burster charge in underwater ammunition. It has already become obsolete, principally because of its relatively great sensitivity.

Explosive D

The noncommittal designation of Explosive D continues to reflect the aura of secrecy that once surrounded it, in the closing years of the last century. Back in 1888, when it was patented, the development of an explosive insensitive enough to be fired through armor plate without detonating, but only a little less powerful than TNT when it did go off, made it a fit candidate for cloak-and-dagger concealment—almost like a junior league atomic bomb. Today all the world knows Explosive D as AMMONIUM PICRATE, a light yellow crystalline powder. It is related to picric acid (trinitrophenol), an explosive used as an AP projectile filler by some foreign powers.

Like TNT, ammonium picrate is chemically stable, even at temperatures as high as 150°F or over long periods of time, but it doesn't melt easily and must be tamped into projectiles as a powder. However, it will, when moist, react with copper and lead to form sensitive explosive picrates, and will corrode iron and steel. That is why projectile filler cavities are coated with varnish or paint before loading.

Tetryl and Tetrytol

Conscientious chemists call it trinitrophenylmethylnitramine (a name which you need learn only if you want to impress your friends), but we call it by the time- and space-saving name of TETRYL. This yellow crystalline substance is used as a burster in 20-mm projectiles, and in booster charges for mines and torpedo war heads. Mixed with fulminate of mercury, it can be used as a detonator. If you mix 75 percent tetryl with 25 percent TNT, you have TETRYTOL, a well-known demolition charge explosive. Both tetryl and tetrytol are stable at ordinary temperatures.

PETN

For the jawbreaker "pentaerythritoltetranitrate" we say "P-E-T-N." This explosive is used only in demolitions, where it forms the active ingredient in detonating cord (commercial name: "Primacord") and as the base charge in blasting caps. As high explosives go, it is quite insensitive (in detonating cord), but has a very high velocity of detonation. Its violence of explosion explains why it is used in demolitions work to initiate the detonation of main charges. In spite of its insensitivity, demolition materials containing PETN must always be treated as the high-explosive stuff they are.

Mercury Fulminate and Lead Azide

MERCURY FULMINATE is a heavy, crystalline solid, white when pure, but usually slightly brown or gray. In most important respects, it is as different from the other high explosives we have studied as it can be. By one standard measurement, it is just 60 times more sensitive than TNT. Yet it is less than two-thirds as powerful. Most other explosives, both high and low, detonate more quickly if you increase the pressure on them. (In fact, in open air, TNT and most other explosives may burn rather quickly, but will usually not explode.) Fulminate detonates when set off by a hot wire, a spark or flames, or by impact. But under extreme pressure (on the order of 25,000 psi and up), it won't even burn, though it will detonate if set off by other fulminate. Lastly, most other explosives are manufactured in bulk, while fulminate is manufactured in lots as small as 1 pound at a time.

Because it's such ticklish stuff, it is fortunate that mercury fulminate can be used effectively even in quantities of 15 to 30 grains (about three seven-hundredths of a pound) to set off other explosives, such as PETN or tetryl (in burster or demolition charges), or black powder (in propelling charges).

Mercury fulminate is adversely affected by moisture, which reduces its sensitivity severely. It must also be protected from prolonged exposure to heat, which causes it to deteriorate. It is now being replaced by other compounds in most applications. A commonly used substitute is lead azide, which is less sensitive to shock, and is therefore less likely to detonate prematurely when used in fuzes for armor-piercing projectiles. It is also more powerful and more resistant to the effects of heat.

So far in this chapter we have discussed explosives in general and the specific military explosives used in the Navy. There are, of course, a number of explosives we haven't taken up at all, since you're not likely to be concerned with them. Some of these are commercial demolition explosives which will be discussed in a more advanced course in this series. And we shall, in another chapter, go into more detail on propellants. But now let us shift our attention to demolition work and the explosives and other materials used in connection with it.

DEMOLITIONS

If you are assigned to the Seabees, your job as GM 2 will often have a lot to do with handling of explosives and demolition materials. Demolition equipment is also issued to many types of ships, and the Gunner's Mates aboard are the men who are responsible for handling it.

The use of explosives and associated blasting gear for construction projects and large-scale demolition involves highly developed skills. To develop those skills requires a good deal of training and experience. No textbook can be a substitute for such training and experience—nor is this one. This section is intended only as an introduction to the subject.

In this chapter we shall take up only those items of demolition equipment that are at present commonly issued

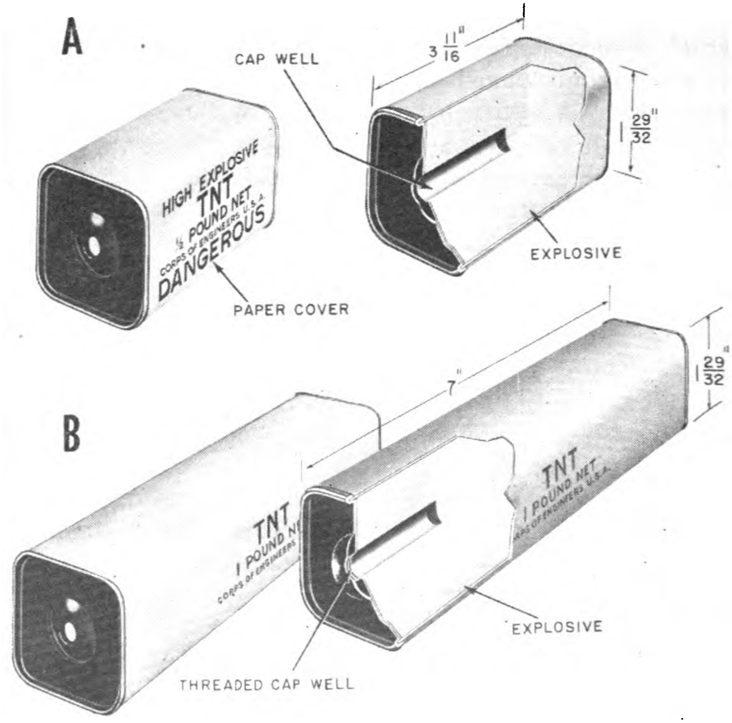


Figure 2–5.—TNT blocks. A. ½-pound block. B. 1-pound block.

to ships of the Fleet. For a much more detailed discussion, which includes other demolition equipment and techniques, you should read the appropriate chapter in the NAVY TRAINING COURSE for *Gunner's Mate 1 & C* (NavPers 10186).

Demolition Charges

The demolition explosive usually issued to ships is most often TNT, in cast or pressed form, but it may be tetryl. The explosives come in half-pound and 1-pound blocks (fig. 2–5). TNT is also the main component of the 55-pound DEMOLITION CHARGE.

The half-pound and 1-pound blocks are issued in cardboard boxes, and can be used either by themselves or as boosters to set off larger charges. Both sizes are made with CAP WELLS (or ACTIVATOR WELLS) into which you can insert BLASTING CAPS (which we shall presently explain).

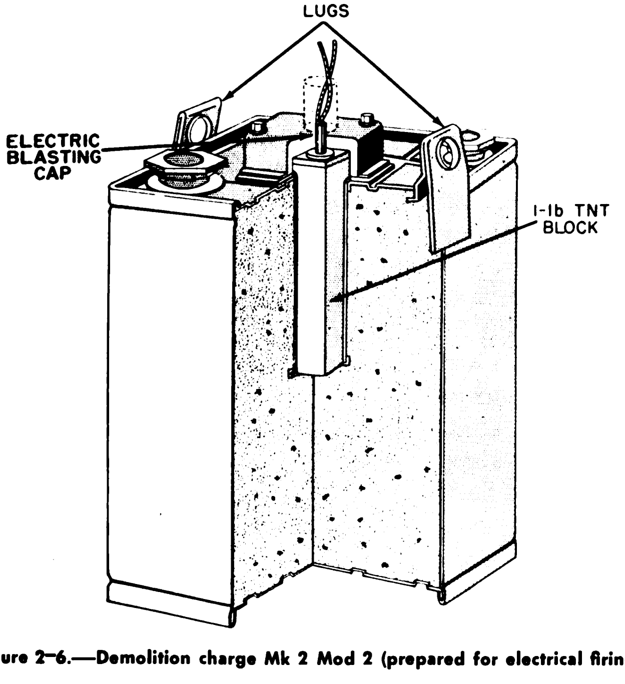


Figure 2–6.—Demolition charge Mk 2 Mod 2 (prepared for electrical firing).

The Mk 2 demolition charges (fig. 2–6) now issued to ships have rectangular rust-resisting steel cases a little over 9 inches square and not quite 13 inches high. Mods 2 and 3 (earlier mods are obsolete) are similar except that Mod 2 has handling lugs. The 1-pound TNT block that is used as a BOOSTER to detonate the charge fits into a cavity in the main cast charge; the blasting cap that sets off the 1-pound block is screwed into the block's activator well. Figure 2–6 shows the charge as set up for blasting. The blasting cap is not inserted until just before the charge is set off.

Electric Blasting Caps

There are two kinds of blasting caps—ELECTRIC and NONELECTRIC. In this chapter we shall take up only the electric caps and associated equipment, since that is what you are most likely to find on shipboard. For information on nonelectric caps and the equipment and methods used with them, look up the NAVY TRAINING COURSE for *Gunner's Mate* 1 & C (NavPers 10186) or the reference publications listed elsewhere in this chapter.

The electric blasting caps issued to the Fleet are not identical with commercial caps. TNT requires a stiff jolt to set it off, as compared with commercial explosives like dynamite; and the special caps you will use pack quite a punch. By the way, this is as good a time as any to point out that ALL blasting caps are sensitive, and must be handled with care. Electric caps are no exception.

The functioning of electric blasting caps is simplicity itself, as you can see from figure 2–7. An electric current heats up a BRIDGE WIRE, setting off the heat-sensitive PRIMING CHARGE, which in turn sets off the PETN BASE CHARGE. This detonates the TNT block into which the cap has been inserted; if the block is the booster to a larger main charge, the train of explosions comes to an end with the detonation of the main charge.

Three makes of special electric blasting caps are standard issue: DuPont, Hercules, and Atlas, all shown in

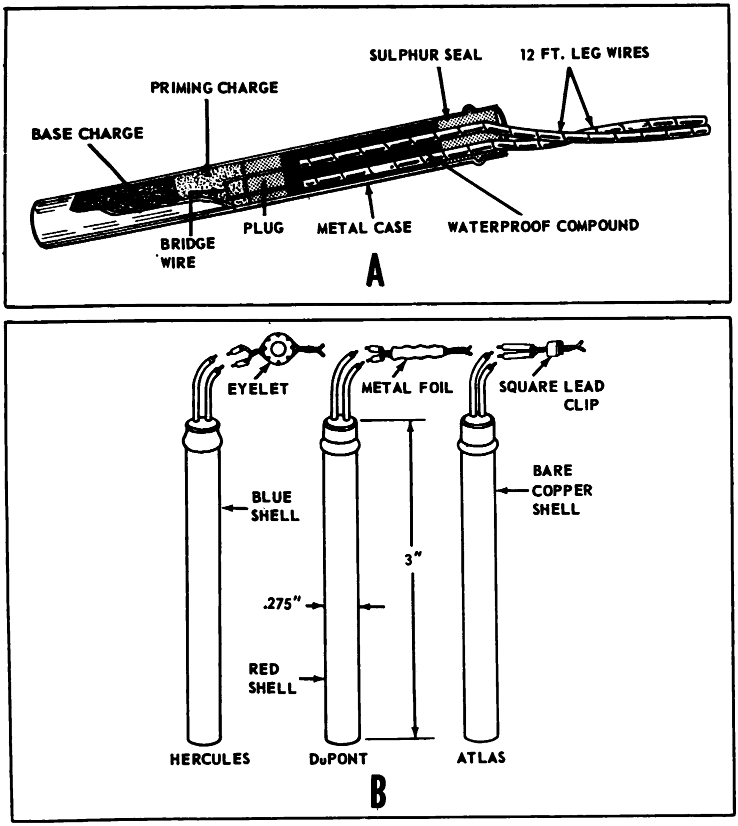


Figure 2–7.—Special electric blasting caps. A. Cutaway view. B. How to identify electric blasting caps by manufacturer.

figure 2–7B. Note the distinctive coloring. Remember that two or more electric caps connected in the same circuit must be the product of the same manufacturer. This is essential to prevent misfires, because caps of different manufacturers have different electrical characteristics. All three makes are waterproofed, and can be used under water if necessary.

Note also the metal short-circuiting devices (SAFETY SHUNTS) on the leg wires that help prevent accidental

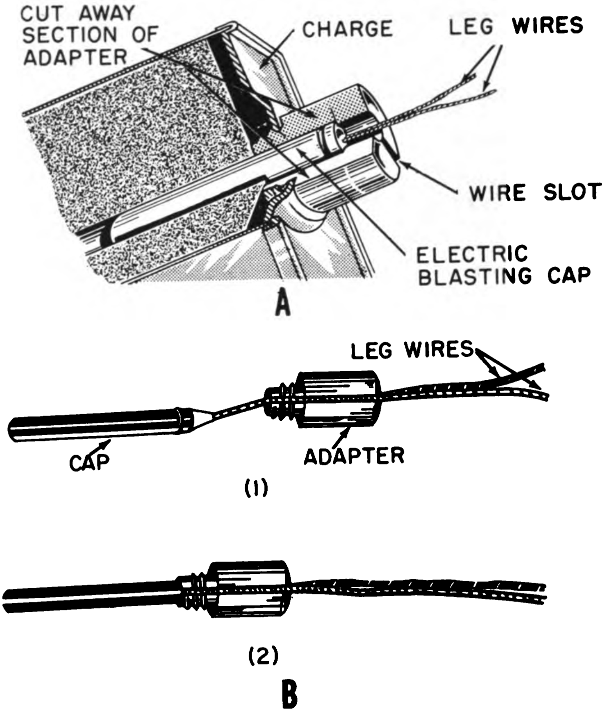


Figure 2–8.—The priming adapter. A. Priming adapter and electric blasting cap assembled into charge. B. How to assemble the priming adapter and cap before assembly into charge.

detonation of the caps by stray electrical currents. These must NOT be removed until just before the cap is wired into the firing circuit.

The electric blasting cap fits into the activator well of the demolition charge. But it doesn't fit tightly, and can easily slip out. To hold the cap in the charge you use a PRIMING ADAPTER, a small plastic cylinder that screws into the threaded end of the TNT block and holds the cap in place. Figure 2–8 shows the adapter assembled in the block, with part of the adapter cut away to show how it holds the cap in place. Figure 2–8 illustrates the two steps in assembling the adapter and cap before they go into the charge. These steps are described in the next section of this chapter.

The other equipment used for electrical firing of demolition charges include a BLASTING MACHINE for supplying current to the blasting cap, wire or cable of required length (the cable may be on a special REEL like the one shown in fig. 2–10B) for connecting the machine to the charge, insulating tape for protecting the splices which connect the cable to the caps, and a CIRCUIT TESTER OR BLASTING GALVANOMETER for testing the circuit before you fire the charge. You also need a knife for working with the wire.

Basic Procedure for Setting Up a Circuit and Blasting

To qualify as a second-class Gunner's Mate, you must be able to demonstrate your ability to work with the demolition equipment on your own ship. In general, this will most likely mean that you will have to show that you can work with the equipment we have discussed so far in this section. Of course, nothing you read here or elsewhere will make you a genuine expert with demolitions. You need real training and experience with the gear for that. But, so that you can see how all the equipment we have described is used together, let's take up, step by step, the procedure for preparing and setting off a demolition setup, using demolition charges Mk 2 (or Mod 3) and electric blasting caps.

1. Determine where the charges are to be placed. This, of course, depends on what is being demolished and the purpose of demolition. If you're sinking a floating hulk that's a menace to navigation, place the charges so that the hulk will go down promptly in water deep enough so that it will be out of the way. And make sure that all WT doors are open. If you're scuttling your own ship (this sad possibility is fortunately not frequent, but it might be necessary in the event of imminent capture by the

enemy), you must, in addition, make it as difficult as possible for anybody ever to use the ship again. Or you may be wiring up small charges to be used in destroying secret or confidential equipment against the possibility of capture. You'll be guided by orders from competent authority, but you must know something about demolition techniques.

2. Usually you will set off several charges at once. To do this, you place the charges, and make up a CIRCUIT which includes the blasting machine and all the charges in series. First you wire in all the caps, then connect them to the cable, and then test the circuit. Here are these steps in more detail:
   a. Make sure your caps are all of the same manufacture. Caps of different make should NEVER be used together in one circuit. Be sure not to use more caps than your blasting machine is designed to handle; it's better to use fewer. When you take caps out of their box, don't try to pry them loose with a sharp instrument; use your fingers, and slide them out carefully. Examine the caps before wiring them up; reject any that show signs of moisture or corrosion. Remove the safety shunt of each cap only when you are actually wiring it up, not before.
   b. You connect the electric cap's leg wire to the bare end of the cable (or to the next cap in the circuit) by twisting the wires tightly together to make a pigtail, then bending the pigtail to one side so that it lies along the wire. Wrap friction tape around the splice. In parallel conductors, STAGGER the splices. You wire the caps in SERIES so that current from the blasting machine passes through all of them in turn. The COMMON series circuit (fig. 2–9A) connects the caps in turn. The LEAPFROG circuit (fig. 2–9B) skips alternate caps so that if the charges are laid out in a row a long return line will not be needed.

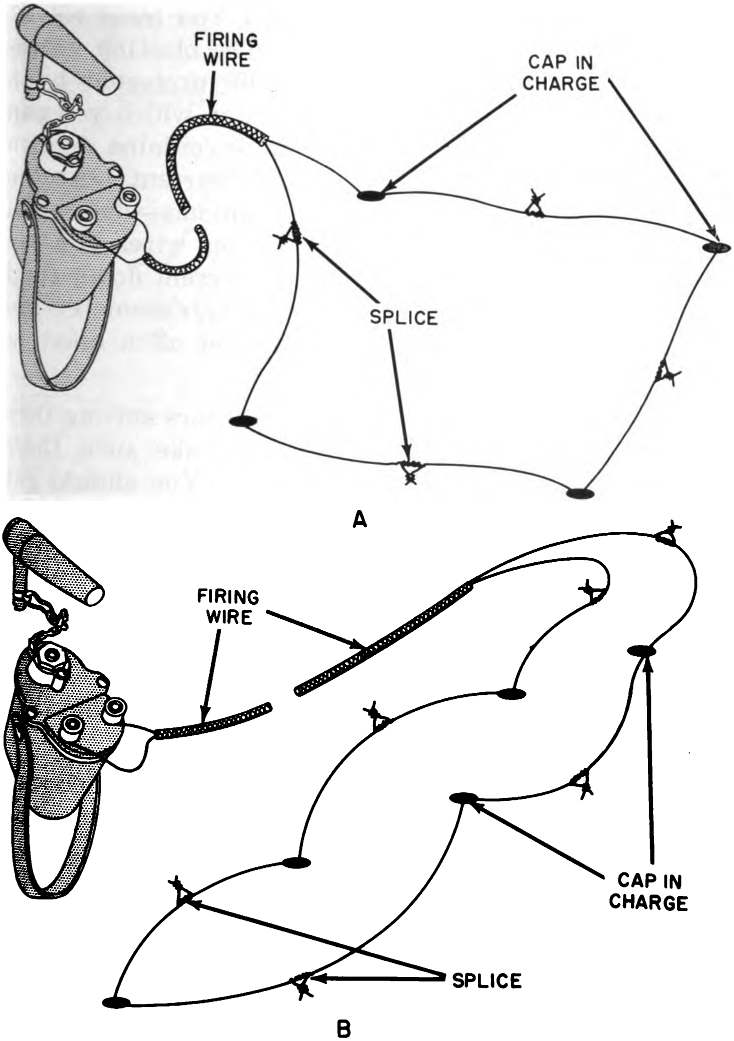


Figure 2–9.—Wiring electric blasting caps. A. Common series circuit. B. "Leapfrog" series circuit.

c. You make electrical tests for demolition setups with only ONE instrument—the BLASTING GALVANOMETER (See fig. 2–10A.) You must NEVER use any other instrument. The blasting galvanometer is in a box, usually protected by a leather case, with a dial face on which you can see the galvanometer needle. It contains its own small battery as a source of current. At the base of the box are two terminals—flat metal discs. You test by touching the wires you are testing to the terminals. If current flows (and the currents indicated by the galvanometer are very tiny ones that will not set off a blasting cap), the needle deflects.

d. First you test both cable conductors BEFORE they are connected to anything. (Make sure their ends are not twisted together.) You should get NO steady indication on the galvanometer. (But it's O. K. for the needle to flick, then return to zero.) If you DO get a steady galvanometer needle deflection, there is a current leak or short circuit in the cable (caused by defective insulation or conductors touching each other). If the trouble cannot be rectified, use other cable that will test O. K.

e. Next, you wire the cable to the caps (but do NOT connect the blasting machine). Test the complete circuit by touching the cable terminals at the "reel end" (where the blasting machine will be connected) to the galvanometer. (See fig. 2–10B.) This time you SHOULD get a definite steady needle deflection. If you don't, go over your circuit and repair it where it's broken. Test each splice and cap individually, if necessary. Or you may use the procedure described in the next section of this chapter for locating breaks in the circuit.

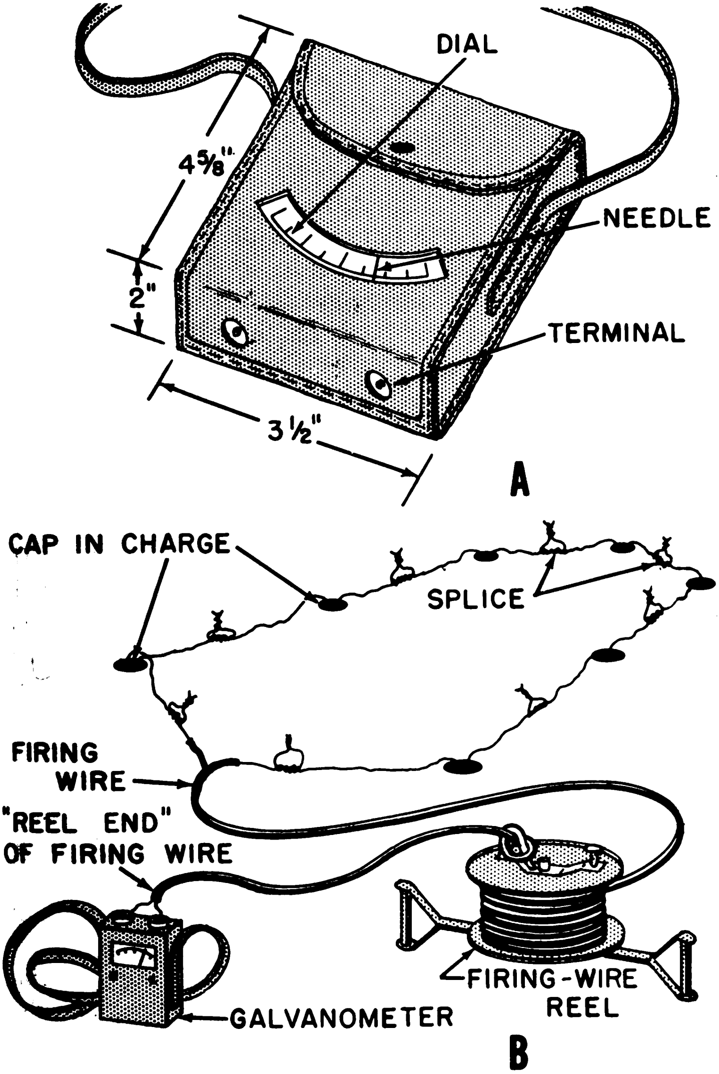


Figure 2—10.—A. Blasting galvanometer. B. Testing the firing circuit.

f. After testing the circuit, the next step is to set each blasting cap in its charge. Open the top of the charge shipping box. (The charge need not be removed from the shipping box to be used, however.) Break the paper seal protecting the activator well in the booster but don't use the blasting cap as a tool. Make sure there is no dirt in the well. Then slip the leg wires of the cap through the priming adapter's wire slot, with the threaded end of the adapter pointing toward the cap (fig. 2–8).

If the leg wires don't slide readily through the slot, don't try to force them by pulling on the cap. Grasp the wires about 6 inches from the blasting cap and slide the adapter slot along the wires away from the cap. Tilt the adapter as you do this, to make the entry of the wires easier.

Now insert the cap gently all the way into the activator well; hold the adapter away from the cap until it's all the way in. Then work the adapter down the wires until it reaches the well, and screw it in gently but firmly as far as it will go. Last, tie the wires so that the cable doesn't strain them at the cap. The Mk 2 Mods 2 and 3 charges have cable anchors under the bolts in the booster covers that can be used to secure the cable.

If you haven't yet tested the circuit, do it now. If time permits, it may be a good idea to do it again even if you tested it before assembling the caps into their charges.

3. The last step is to connect the blasting machine. Make sure everything else is in readiness, and that all personnel have cleared the danger area. Connect the cable to the blasting machine. Most blasting machines have removable handles; don't put the handle on until AFTER the machine is connected, and

just before you blast. To operate the machine, twist the handle smartly through its full range.

4. If the blast does not occur, REMOVE the handle of the machine (and put it into your pocket to make sure nobody operates the machine inadvertently) and DISCONNECT the machine. Then, and only then, is it safe to investigate the trouble further.

Procedure for Locating Breaks in the Firing Circuit

Here is a way (illustrated in fig. 2–11) in which a break in the firing circuit may be located if the circuit test from the reel end indicates an open circuit, or if you have a misfire.

1. First disconnect the blasting machine. Make sure the two wires at the reel end of the firing cable are separated and not touching any conductor.
2. Connect the two spliced wires at the far end of the firing cable (C and D in fig. 2–11) with the blasting galvanometer. (Don't break the splices; just touch

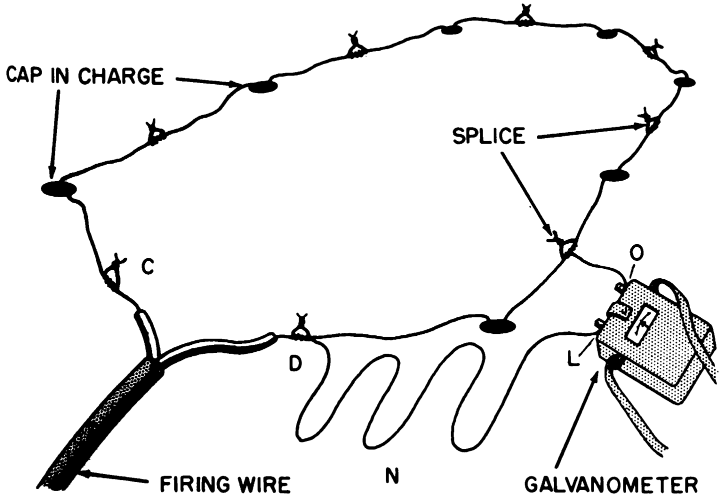


Figure 2–11.—Locating breaks in the firing circuit.

them to the galvanometer's terminals.) If the instrument now shows a complete circuit, these connections or the cable are faulty.

3. If the galvanometer still shows an open circuit, connect splice D to one terminal (L) of the galvanometer, using a wire (N) long enough to reach all connections in the circuit. Move around the circuit with the galvanometer, touching the other terminal (O) to all splices in succession. At the first point where the instrument shows an open circuit, you know that there is a break between that point and the previous one.

If the break is accessible, splice the broken wire. If the cap is defective, replace it if possible. If you can't, handle it as a misfire; use additional priming, or set up another charge close by. After this repair, continue the test to locate additional breaks. When all are repaired, test the circuit again from the reel end.

Precautions

Here is a brief summary of precautions to ensure both reliability and safety, which you should bear in mind when blasting with electric caps:

1. Use only Army Engineer Special blasting caps of the types described above for military demolitions. Other caps are weaker and may cause misfires.
2. Use only ONE brand of cap in any one circuit.
3. Before using a blasting cap, inspect it for moisture. If you see any sign of dampness, use another cap. Never use a sharp instrument to pry a cap out of its box. And never take a cap out of its box unless you intend to use it.
4. All the wiring in an electric blasting circuit must be the responsibility of ONE person only, and that man must know his job. He should keep the blasting machine, or its operating handle, on his person while the circuit is being wired, to avoid accidental firing.

5. Before firing or testing, be sure the safety shunts are removed from all caps, but don't remove the shunts until you are actually wiring the caps into the circuit. If shunts are missing, keep the cap wires twisted together.
6. NEVER fail to use the blasting galvanometer to test your complete circuit before the blasting machine is connected. Don't depend on visual inspection only. Use NO OTHER device to test the circuit. Dry-cell powered ohmmeters, for instance, may set off the blasting caps.
7. NEVER yank the leg wires of an electric cap, or subject them to any steady pull. This is important to remember when you're installing the priming-adapter. Secure the leg wires and firing cable with strong twine or other fastenings so that pulls on the cable will not be transmitted through the splice or to the cap.
8. Don't connect the cable to the blasting machine until you're ready to fire and the danger area is clear. Unless you are actually testing the circuit or you are actually making ready to blast, it's a good idea to keep the free ends of the cable twisted together.
9. Avoid setting up an electric blasting circuit when there is a thunderstorm brewing. In general, protect electric blasting caps, whether in circuit or not, from any stray electric currents.
10. When you use the blasting machine, twist the handle sharply to be sure you get enough output to fire. If the machine has a thong, wrap it about your wrist to prevent the machine from slipping when you twist. Immediately after the blast, disconnect the machine and twist the cable conductors together. If your circuit misfires, try once more. If it misfires again, disconnect the blasting machine, put the handle in your pocket, and twist the

cable conductors together BEFORE you try to investigate the cause of misfire.

References

With what you have read here, you will have a head start on learning to use the demolition equipment that is issued in accordance with most ship ordnance equipment lists. Here are some references you can look up if you want to learn more about demolitions.

NavPers 10186: *Navy Training Course for GM 1 & C*

Navy OP 1411: *Safety in Combat Demolition Installation and Blasting for Underwater Combat Teams*

Navy OP 1471: *Demolition Charges Mk 2 Mods 2 and 3 and Demolition Conversion Kit Mk 17 Mod 0*

OP 1178: *Demolition Material*

Army Field Manual FM 5–25: *Explosives and Demolitions*

Army Field Manual FM 5–31: *Land Mines and Booby Traps*

Army Technical Manual TM 5–220: *Passage of Obstacles Other Than Mine Fields*

Army Technical Manual TM 5–252: *Use of Road and Airdrome Construction Equipment*

Army Technical Manual TM 9–1940: *Land Mines*

Army Technical Manual TM 9–2600: *Military Explosives.*

DuPont Co. Explosives Department: *Blaster's Handbook*

Other references are listed in OP 0 and OP 1178.

QUIZ

In each of the following, select the one BEST answer.

1. Nitrogen compounds are the main component of most military chemical explosives because
   a. nitrogen is chemically very active
   b. many nitrogen compounds are unstable
   c. nitrogen atomic nuclei are unstable
   d. explosions produce large quantities of heat

2. The term "brisance" refers to the
   a. shattering ability of an explosive
   b. sensitivity of an explosive
   c. energy content of an explosive
   d. amount of nitrogen in an explosive

3. The function of the booster in the explosive train is to
   a. provide for setting off the main charge sympathetically
   b. increase the amount of flame produced by the initiating explosive
   c. ignite the main charge
   d. detonate the main charge

4. In which of the following applications of explosives are LOW explosives ALWAYS used?
   a. Propellants
   b. Bursters or disrupters
   c. Initiators
   d. Auxiliaries

5. In a bag gun propelling charge primer, which of the following explosives is used mainly for producing a flame to set off the igniter?
   a. Tetryl
   b. Granular TNT
   c. Black powder
   d. Lead azide

6. One of the causes of the difference between old and new gun barrel profiles illustrated in figure 2–3 is
   a. black powder explodes with a sharper shock than modern propellants
   b. average propellant gas pressure is lower in modern guns
   c. black powder burns more slowly than modern propellants
   d. a longer bore is now used so that more propellant can be loaded behind the projectile

7. Pyro powder is mainly composed of
   a. diphenylamine
   b. nitrocellulose
   c. ether and alcohol
   d. nitric and sulfuric acids

8. The stabilizer in SPCG is
   a. nitroguanidine
   b. carbamite
   c. nitroglycerin
   d. diphenylamine

9. The main advantage of ballistite over single-based powders as a rocket propellant is that
   a. it contains nitroglycerin
   b. its high burning temperature increases erosion
   c. it burns smoothly at low pressures
   d. it produces high burning pressures
10. Rocket motors that have been exposed to excessive temperatures
    a. may not be fired under any condition
    b. must be cast overboard immediately
    c. must be fired before they have had a chance to cool off
    d. may not be fired until they have cooled off preferably for at least 6 hours
11. TNT is not used in
    a. armor-piercing projectiles
    b. demolition charges
    c. depth charges
    d. mines
12. Which of the following explosives based on RDX is used chiefly in demolition charges?
    a. HBX
    b. Composition A
    c. Composition B
    d. Composition C
13. In demolition setups using electric blasting caps, the bridge wire
    a. is used to connect the caps in series
    b. must never be put in the same circuit with the blasting galvanometer
    c. sets off the priming charge when the firing circuit is closed
    d. must not be removed until just before the cap is wired into the firing circuit
14. The source of current for the blasting galvanometer is
    a. the generator in the blasting machine
    b. an external battery
    c. a battery in the blasting galvanometer
    d. a break in the insulation of the firing cable
15. The best time to remove the safety shunt from each cap is
    a. as soon as the box of caps is opened for the first time
    b. just before wiring the cap into its circuit
    c. right after testing all caps in the circuit
    d. right after connecting the blasting machine

CHAPTER 3

AMMUNITION

INTRODUCTION

In the preceding course in this series you learned what ammunition in general is. You learned how to identify the principal types of ammunition, and you were introduced to the main components of some types.

Ammunition, as you remember, is classified as—

1. Gun ammunition:
   - a. Bag
   - b. Semifixed
   - c. Fixed
   - d. Small-arms (in reality a subclass of fixed ammunition)
2. Bomb-type ammunition:
   - a. Torpedo war heads
   - b. Aircraft bombs
   - c. Depth charges
   - d. Mines
3. Pyrotechnic ammunition
4. Rocket ammunition
5. Impulse ammunition
6. Demolition charges and components

In this chapter we'll take up in detail GUN AMMUNITION (other than small arms) and PYROTECHNICS. We'll study their construction, functioning, and maintenance.

GUN AMMUNITION—PROPELLING CHARGES

On the basis of their propelling charges, you remember, all gun ammunition is of two main kinds. One is BAG type (or SEPARATE LOADING) in which the propelling charge comes in two or more separate silk bags, with a separate primer. The other is CASE-type, in which the primer and propelling charge are housed together in a cylindrical metal cartridge case. In turn, case ammunition is of two main kinds—FIXED, in which the complete round consists of a cartridge case and projectile secured together in one place; and SEMIFIXED, in which the complete round consists of two pieces: the propelling charge (complete in its plugged case), and the projectile. (Small-arms ammunition is fixed ammunition, but we take it up elsewhere in this course.)

Bag-Type Propelling Charges

The separate ammunition details that go to make up a complete round of separate-loading ammunition are the PRIMER, the POWDER BAG (usually two or more, depending on caliber of gun and type of load prescribed), and the PROJECTILE.

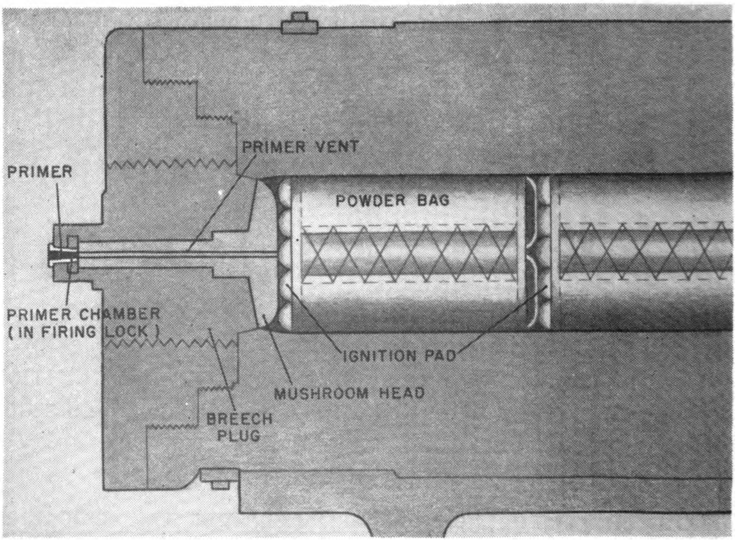


Figure 3–1.—Elements of a complete propelling charge (separate-loading ammunition).

Lock Combination Primer

The cross-section view of figure 3–1 shows these details (except for the projectile) in a loaded and primed bag gun: The primer fits into the chamber of a FIRING LOCK on the rear face of the breech plug. The primer's open end faces into a tubular PRIMER VENT that leads into the chamber, in which are the powder bags.

The primer itself (fig. 3–2) looks like a small tapered cartridge case, with a rim at the base. Inside, behind the round central part in the base, is an impact-sensitive percussion cap. Connected to this same part is a bridge wire (like the one in an electrical blasting cap) surrounded by a wisp of guncotton and a priming mixture containing mercury fulminate. Either the impact (of a firing pin) or an electric current (from a firing circuit)

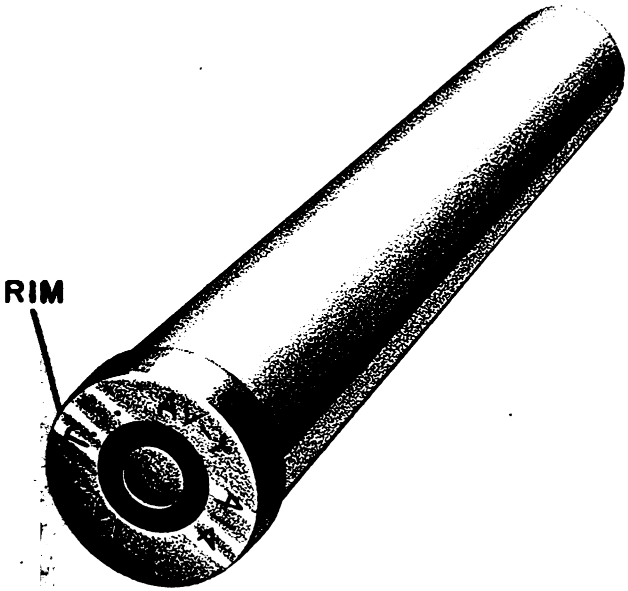


Figure 3–2.—Lock combination primer (exterior).

in the bridge wire can set off the primer's flame-producing contents. The flame issues through the primer vent (fig. 3–1) to the gun chamber, where it ignites the other details of the propelling charge.

Because it fits into the firing lock of a bag gun, this is a LOCK primer. If it had only a percussion cap (and no bridge wire), it would be a PERCUSSION primer. If it had only the bridge wire and its priming mixture, it would be an ELECTRIC primer. But it can be set off either by percussion or by electricity, so it is a COMBINATION primer. Full name of this unit: LOCK COMBINATION PRIMER.

In separate-loading ammunition, loading of the primer into the lock is a completely independent operation from loading of any other ammunition detail. If a primer fails to function, or if there is a misfire for any other reason, the primer may be ejected and a new one substituted without removing powder bags or even unlocking the gun breech.

Other kinds of primers are used in other propelling charges. We'll take them up later.

Powder Bags

Now let's look at the powder bag, which contains the bulk of the propelling charge.

The powder bag is a fabric container, cylindrical in shape when fully loaded with smokeless powder grains (fig. 3–3A). The fabric is silk, which will burn completely when the charge is fired, leaving no smoldering embers. The lacings and bag handle straps are of the same material, for the same reason. Each bag contains its own black powder IGNITION CHARGE in a red-dyed pad sewed like quilting to one end of the bag.

The grains of smokeless powder may be either packed into the bags loosely (UNSTACKED), or STACKED so that all the grains are arranged in layers with the grains standing more or less vertically (fig. 3–3B). Stacked charges are more compact and easier to handle, and the sharp edges of the grains are less likely to cut the bag fabric.

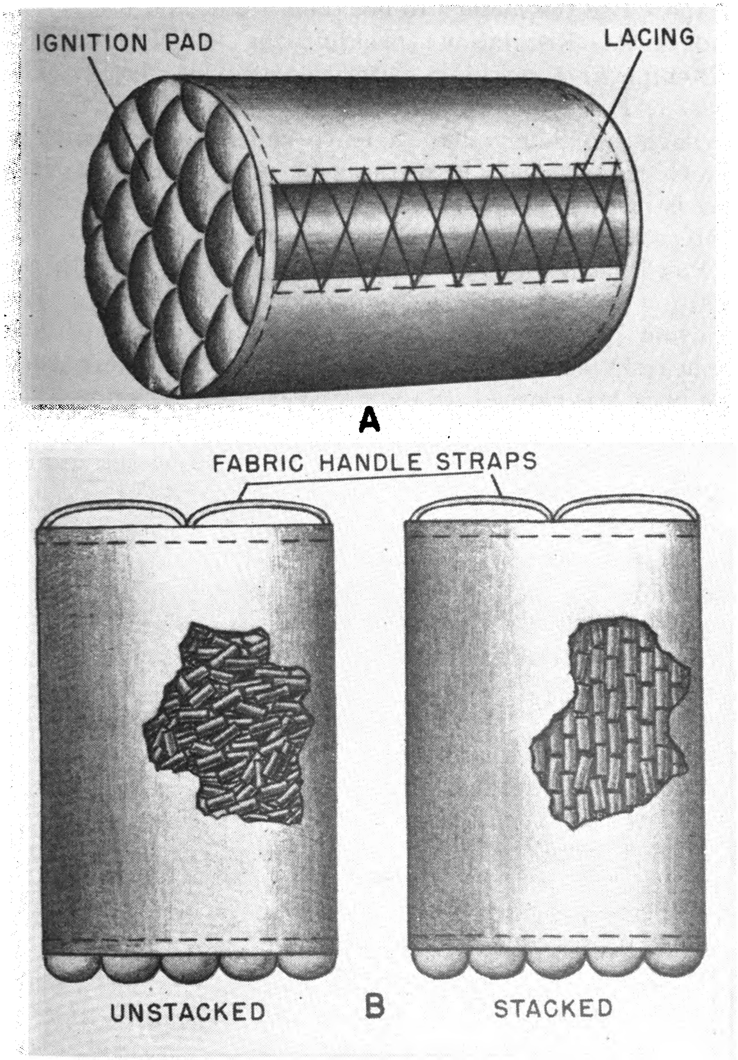


Figure 3–3.—Powder bags.

Because old bags tend to get slack and flabby, you may have to do a little work on them to get them back into shape. Use the lacings to get them tight, and use NOTHING ELSE. Regulations prohibit the addition of ANY stiffening or tightening material to powder bags. The reason: Foreign material added to the bag is likely not to burn completely, but to leave embers and sparks in the chamber to set fire to the next round's charge. If a bag is in such poor shape that it is unsafe to rely on the lacings to get it tight, replace it with another.

Powder bags are always loaded into the gun with the ignition pad aft, facing the breech plug (fig. 3–1). The ignition pad of the rearmost bag must come within 4 inches of the mushroom head on the face of the plug when the breech is closed. If the rearmost bag is rammed too far in, you can, without opening the breech, usually get it to slide back to the mushroom by elevating the gun to its highest angle.

However, if the rearmost powder bag is loaded wrong-end-to, the result probably will be either a hangfire or a misfire. The usual procedure for dealing with this is to continue firing primers until the charge is set off. But an alert gun crew will never let it happen to start with.

Smokeless powder must be stored in airtight, watertight containers called POWDER TANKS. (Later in this chapter we shall discuss the characteristics of smokeless powder that makes this kind of stowage necessary.) There are several types; one is illustrated in figure 3–4. Note the top cover, which is designed for tight sealing and quick opening, using the special wrench required. Larger tanks, like the one illustrated, have lugs for use with slings; smaller ones have handles.

Especially in bag gun turrets, regulations strictly limit the number of tanks that may be open at any one time.

Case-Type Propelling Charges

A complete round of semifixed ammunition consists of TWO pieces: a projectile, and a cylindrical metal cart-

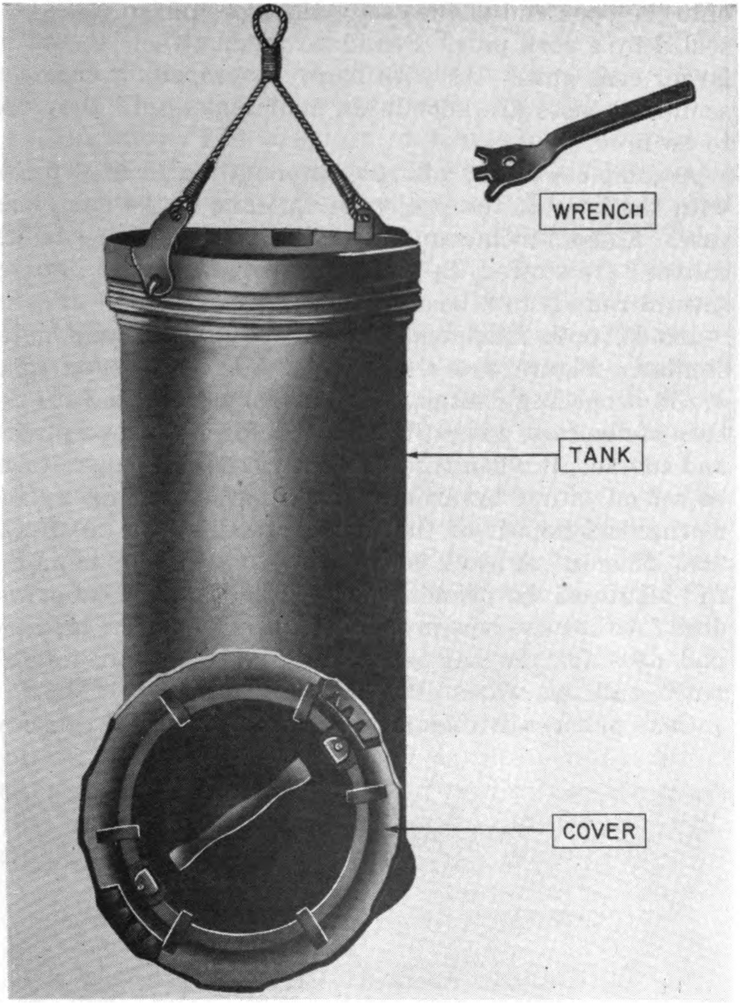


Figure 3–4.—Powder tank, cover, and wrench.

ridge case sealed by a plug and containing the propelling charge and primer.

In some semifixed ammunition, a plastic plug is crimped onto the open end of the case. Other semifixed cases are sealed by a cork plug. Semifixed ammunition is used in larger case guns. As with bag-type propelling charges, semifixed cases are kept in airtight tanks until they are to be fired.

A complete round of fixed ammunition is ONE piece, with the base of the projectile CRIMPED to the cartridge case. Fixed 3-inch rounds are kept in tanks, but smaller calibers are stowed, as you remember, in airtight boxes, several rounds to a box.

Inside, both fixed and semifixed cartridges are quite similar. Figure 3–5 shows the main components of a 5"/38 propelling charge. The primer's base fits into the base of the case, so that the gun's firing pin lines up with and contacts it when the breech is closed. Because it can be set off either by an electric firing current or by the mechanical impact of the firing pin, this is a COMBINATION primer. A black powder IGNITION CHARGE runs the full length of the primer's perforated STOCK or tube, and does for the case-type propelling charge what the ignition pad does for the bag-type charge. To give it its full name, call this a CASE COMBINATION IGNITION PRIMER.

Case primers with ignition charges and with percus-

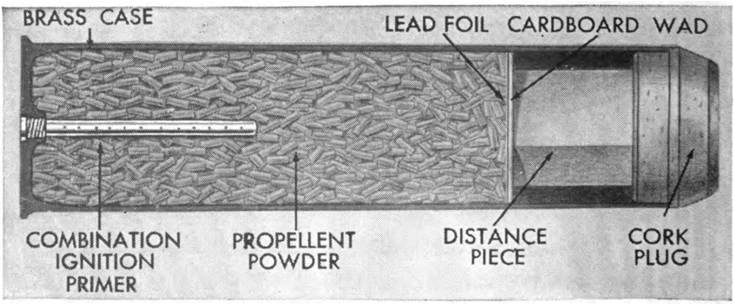


Figure 3–5.—Cartridge case (5"/38) in cross section.

sion caps, but lacking provision for electrical initiation, are CASE PERCUSSION IGNITION PRIMERS. They are used in ammunition for the new base-ring type 3"/50 mounts, and elsewhere. In ammunition 40-mm and smaller, the entire propelling charge is so small that no igniter is necessary. Since these have no provision for electric firing, they contain simple CASE PERCUSSION PRIMERS.

WARNING: You are NOT authorized to disassemble service ammunition to get at primers, nor to disassemble live primers. The explosive compounds in them, as you certainly have learned from the preceding chapter in this course, are exceedingly touchy stuff. Even if a primer hasn't enough wallop to blow you to bits, it can certainly deprive you of a finger or an eye, and it can easily set off more powerful charges. Under proper supervision you may, of course, use test primers, designed for the purpose, to check the functioning of firing mechanisms and circuits.

Remember to play safe with primers when they're assembled into their charges, too. Handle semifixed cartridge cases, when they're out of their tanks, with base UP, so that you won't accidentally set the case down on the deck, where a rivet head can set off the primer. Similarly, load them into their hoists base up.

Now let's look at the case in figure 3–5 again. When the gun fires, the case expands under the powerful pressure of the burning propellant gas, then must contract again afterward so that it can be removed from the chamber. It mustn't stick to the chamber walls, nor may it crack. For a long while, only seasoned brass cases could be relied on to perform correctly. During World War II, when the supply of brass (the metal, that is) became critical, metallurgists developed a special steel that served adequately.

Since steel is cheaper and is being improved all the time, you'll see more and more steel cases as time goes on. But whatever they're made of, used cases are still called "spent brass." However cheap they are (relatively), they still cost the taxpayer something. That is why Navy directives require you to save spent brass, to try to keep it from getting too badly battered, and to return it to ammunition depots for reworking.

Immediately after firing, ejected cases (5-inch and larger) should be stood on their bases to permit residual gases (small amounts left over after firing) to escape completely. Then replace the cases in their tanks, tag as empty, and stow. This procedure applies to all case ammunition supplied in tanks. Other spent brass should be replaced in the original containers, tagged, and stowed.

In the center of the base of the case is the threaded hole for the primer. The case tapers slightly toward the forward end, so that it can be withdrawn from the chamber without binding. A rim at the base engages the gun's extractors. In fixed ammunition, the case often has a bottle neck in which the projectile is crimped.

The PROPELLENT POWDER in the case is the 7-perforation kind we have already studied. (Small-caliber grains have one perforation.) The powder is weighed out with great precision and loaded into the case at the ammunition factory. Since it does not take up all the space inside the case, and since it would be dangerous for the powder to have a lot of room to rattle around in, it is tightly packed and sealed under a sheet of lead foil and a cardboard wad. These are kept tight by a triangular cardboard DISTANCE PIECE. The distance piece bears up against the PLUG that closes the mouth of the case. In fixed ammunition, the case is sealed by the projectile base.

The lead foil functions as more than a packing material. When the gun is fired, it helps clear the bore of the METAL FOULING that scrapes off the projectile rotating band onto the rifling as the projectile passes through the barrel.

PROJECTILES

If you were to cut open for inspection all the different types of gun projectiles (20-mm and larger) used in the

Navy, you would find that they could be classified into four general types (three of them illustrated in fig. 3–6) and a number of subordinate types, more or less as follows:

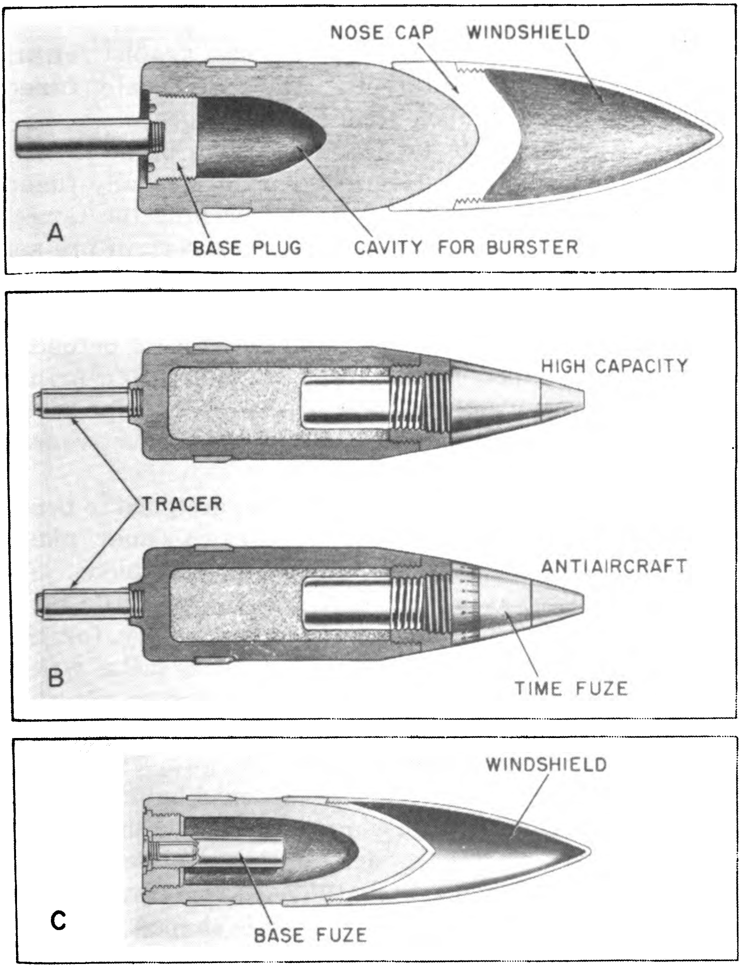


Figure 3–6.—Types of standard Navy projectiles. A. Armor-piercing (AP). B. Thin-walled: High-capacity (HC) and antiaircraft (AA). C. Common (COM).

1. THIN-WALLED projectiles, designed to inflict damage by BLAST EFFECT and by FRAGMENTATION (breaking up into small high-speed fragments). Note (in fig. 3–6B) that these projectiles have relatively thin walls and a large cavity for the bursting charge. The important kinds of thin-walled projectiles are—
   a. HIGH-CAPACITY (HC), for use against unarmored surface targets. They are usually fuzed to function upon striking the target.
   b. ANTIAIRCRAFT (AA), designed to burst in air, for use against aircraft. They are usually fuzed to function either upon approaching the target (VT or PROXIMITY fuze), or at a certain pre-set time after firing (time fuze).
   c. ANTIAIRCRAFT COMMON (AAC) projectiles (not illustrated), equipped with fuzes that detonate either upon impact, or a set time after firing. These projectiles have somewhat heavier walls than AA projectiles, for greater effectiveness against surface targets.
2. ARMOR-PIERCING (AP) projectiles, designed to penetrate resistant obstacles, like heavy armor plate, thick concrete, or the like, and then to explode. As you can see in figure 3–6A, an AP projectile body has thick walls, a relatively small cavity for the burster charge, a NOSE CAP, and a thin metal WINDSHIELD. To function effectively, an armor-piercing projectile must keep its burster charge intact until it has penetrated its target. The projectile body, of tough steel, backs up the hardened but somewhat brittle steel nose cap, which is so shaped that it will dig into and cut through an armor-plated target, rather than bounce off (RICOCHET). However, in flight the blunt nose cap, which is shaped for penetration of armor, not for streamlining, would give the projectile the ballistics of a brick. Hence the windshield, which collapses upon impact with the

target, is screwed on to give the exterior of the projectile a satisfactory ogival shape.

NOTE: Figure 3–6 does not show the burster charge or the base fuze used to set it off.

3. COMMON (COM) projectile, a compromise between the AP and thin-walled types (fig. 3–6C). The walls, though sturdy enough to penetrate thin armor, still permit a cavity large enough to carry a sizable bursting charge. Common projectiles, 5-inch and larger, may have windshields. SPECIAL COMMON projectiles have thicker walls than common, though not quite so thick as AP.
4. SPECIAL-PURPOSE projectiles, which include all those types that are not listed and classified above. Special-purpose projectiles are not intended to inflict damage by explosion or fragmentation. Their purposes depend on type, as follows:
    a. ILLUMINATING projectiles, often termed (informally) STAR SHELLS (SS). These are used for illuminating a target in darkness. The projectile contains a flare attached to a parachute. At a predetermined instant, while the projectile is in flight, the time fuze ignites a black-powder charge. The charge expels the parachute and flare, and lights the flare, which burns with a brilliant light for a fraction of a minute as it descends, supported by the parachute (fig. 3–7A).
    b. CHEMICAL projectiles include a number of different types, depending on purpose—those with various types of war gases, and smoke projectiles. Smoke projectiles (one is shown in cross section in fig. 3–7B) are by far the commonest. They contain tubes of white phosphorous (WP) and a black-powder burster charge, which scatters the tubes over a wide area when it explodes. The smoke is used both for con-

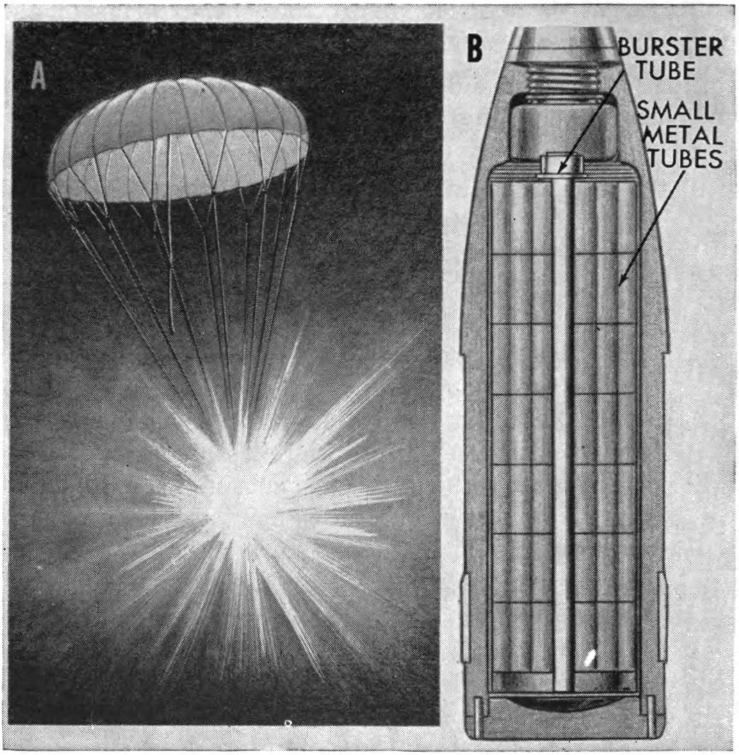


Figure 3–7.—Special-purpose projectiles. A. Illuminating. B. Smoke (WP).

cealment and to harass the enemy, particularly in shore bombardment.

c. TARGET projectiles. These are loaded either with sand or with small spotting charges to help locate point of impact. Their use is indicated by the name.

d. NONFRAGMENTING (or NONFRAG) projectiles are a special type used for training in AA fire against drone target aircraft. In order to avoid damaging the target, the projectile, although ballistically identical to service ammunition, has a small black-powder burster charge which can break the projectile open but is incapable of producing high-velocity fragmentation. The projectile can damage the drone only by a direct hit. The burster charge contains a chemical coloring agent (for example, Epsom salts, which produce a distinctive gray cloud) so that the location of the burst is clearly indicated.

e. LINE-CARRYING and PROOF-SHOT projectiles are highly specialized types of projectiles. Line-carrying projectiles are fired only from special guns designed for the purpose, and proof-shot projectiles are used only at proving grounds.

f. WINDOW projectiles are loaded with metal foil strips and a small burster charge. When exploded at high altitude, the scattered strips hinder operation of enemy radar.

Many types of projectiles, especially 5-inch and smaller, are fitted with TRACERS (fig. 3–6) that burn during projectile flight, leaving a bright trail of light, of use in spotting. Tracers are especially valuable in antiaircraft fire control. In 40-mm ammunition, the tracer may be installed so that when it burns down to its end, it detonates the burster charge. The advantage of this SELF-DESTROYING feature is obvious when AA projectiles are fired at such elevations that they might fall close to the gun that fired them.

Fuzes

In the preceding chapter you learned that the burster charge of a projectile is relatively insensitive, and requires an explosive train, beginning with a very small amount of sensitive initiating explosive, to get the projectile to accomplish successfully its mission of destruction.

The component that sets off the initiating explosive is the FUZE. No matter how complicated or simple its construction or functioning, that is what the fuze is for.

Fuzes can be classified by functions as follows:

1. TIME fuzes function a predetermined length of time after the projectile is fired. The exact time is set, before the projectile is loaded into the chamber, by a mechanical FUZE SETTER on the mount. Or you can set the fuze with a special FUZE WRENCH. The interval between the instant the fuze is set, and the instant the projectile is fired, is DEAD TIME. No matter when, how, or by what it is set, the timing mechanism of a time fuze begins to function only when the projectile is fired.
2. PROXIMITY or VT fuzes are energized when the projectile is fired, and function when the projectile approaches closely to the target.
3. PERCUSSION or IMPACT fuzes function either as the projectile strikes the target, or (especially in AP projectiles) after the projectile penetrates. Some fuzes (nondelay type) of this kind function immediately on contact with any thin material (for example, the thin sheet metal skin of an aircraft). Fuzes for armor-piercing projectiles, however, always incorporate a slight DELAY to keep the burster from going off until after penetration.
4. COMBINATION fuzes incorporate both time and percussion features—that is, the fuze may go off either on impact, or after the time set, whichever occurs first.
5. AUXILIARY fuzes, as the name implies, operate only with other fuzes. In gun projectiles, they form part of the explosive train, and pass on the explosion initiated by another fuze (located in the projectile nose) to the main bursting charge.

If, in the nomenclature of a projectile fuze, there is no mention of function, it's usually an impact or percussion fuze.

The nature of the fuze mechanism depends, of course, on what kind of fuze it is. All fuze mechanisms depend on certain forces either to start their functioning, or to keep them functioning. These forces develop either when the projectile is fired, when it flies through the air, or at the end of its flight. In the sequence of their development, these forces are SETBACK, CENTRIFUGAL FORCE (caused by SPIN), CREEP, and IMPACT. They are worth explaining.

Everything material has INERTIA. For our purpose here, we can say that inertia means resistance to change in motion. A moving ship, for example, tends to keep going even with engines stopped. (And it would keep going indefinitely if it weren't for the fluid friction of the water it floats in, and the obstacles in its way.) A ship dead in the water tends to remain so, and it takes mighty efforts by its propulsion equipment to get it under way.

Back in 1687, in a Latin treatise on natural philosophy, entitled *Principia,* Sir Isaac Newton described this characteristic behavior of material things in the statement of his First Law of Motion:

> **Every body tends to remain at rest, or in uniform motion in a straight line, unless compelled by external force to change.**

(Because Newton's original statement was Latin, you'll find that different translations have different wording, but the idea is the same.)

Why bring up Newton and his laws of motion (in Latin, at that) when we're discussing fuzes? The reason: Every one of the forces that acts on a projectile fuze—from firing to impact—is an effect of inertia.

Let's begin with setback (fig. 3–8A). When the propelling charge of the round fires, the fuzes and projectile are at rest. As the hot gases expand, pressure in the chamber goes up, and forces the projectile to move forward. But because of inertia, every particle of the projectile and fuze tends to stay where it is. The effect—well, have you ever been in a jalopy whose hot-rod driver tramps on the throttle as soon as he sees the light turn green? Your head snaps back as the car jerks forward. The same thing happens in the projectile and its fuze, except that the acceleration—and the setback effect—are thousands of times greater. As an example of its appli-

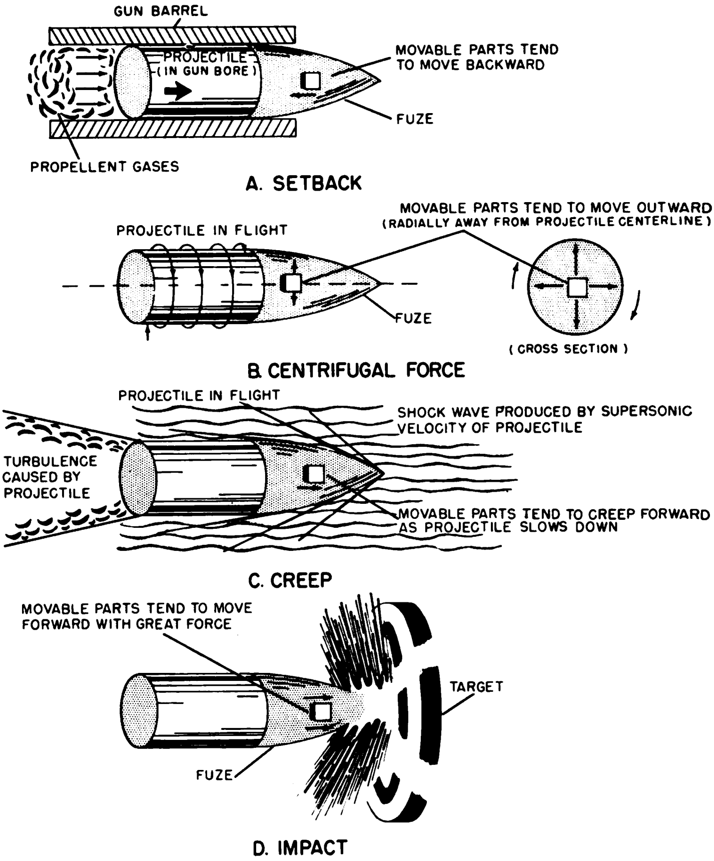

GUN BARREL
PROJECTILE (IN GUN BORE)
MOVABLE PARTS TEND TO MOVE BACKWARD
FUZE
PROPELLENT GASES
A. SETBACK
MOVABLE PARTS TEND TO MOVE OUTWARD (RADIALLY AWAY FROM PROJECTILE CENTERLINE)
PROJECTILE IN FLIGHT
FUZE
(CROSS SECTION)
B. CENTRIFUGAL FORCE
PROJECTILE IN FLIGHT
SHOCK WAVE PRODUCED BY SUPERSONIC VELOCITY OF PROJECTILE
TURBULENCE CAUSED BY PROJECTILE
MOVABLE PARTS TEND TO CREEP FORWARD AS PROJECTILE SLOWS DOWN
C. CREEP
MOVABLE PARTS TEND TO MOVE FORWARD WITH GREAT FORCE
TARGET
FUZE
D. IMPACT

Figure 3–8.—Forces that work on fuzes. A. Setback. B. Centrifugal force. C. Creep. D. Impact.

cation to fuzes, setback is used in mechanical time fuzes to unlock the clockwork mechanism.

As the projectile rotating band is twisted by the gun bore's rifling, the projectile spins. You know how spinning develops CENTRIFUGAL FORCE (fig. 3–8B)—a tendency to fly directly away from the center of rotation. (This is another effect of inertia. A moving object tends to keep moving—in a STRAIGHT LINE. Centrifugal force is caused by a revolving particle's tendency to move in a straight line rather than in a circle.) As an example of its application in fuzes, centrifugal force, instead of a wound-up spring (as in conventional clockwork), is used to operate the clockwork in most mechanical time fuzes. Centrifugal force is also used to assist in readying (ARMING) the fuze to function when it strikes or approaches the target.

Creep (fig. 3–8C) is another effect of inertia. Like anything else that moves through the air, a projectile in flight moves against air resistance, which tends to slow it down. Its supersonic speed creates shock waves and turbulence, which increases this frictional slowing. But the slowing-down effect is applied to the EXTERIOR of the projectile. The parts inside aren't overcoming any air resistance, so they don't tend to slow down. You can notice this effect as it applies to yourself, if you ride in an automobile in which the brake (simulating air resistance) is being applied lightly. You tend to lean forward. Similarly, movable parts in a fuze tend to creep forward as the projectile plows through the air that slows it down. In many types of fuzes, creep force is used to align the fuze firing mechanism so that it will function on impact.

Impact (fig. 3–8D) is probably the most obvious application of the general principle of inertia to fuze. When the projectile strikes, it comes to a stop. But the movable parts inside the fuze tend to keep right on going. You can use the force developed by this tendency to drive a firing pin against a percussion cap to initiate the explosive train. Some people think of impact as a kind of creep—but in a very violent form. In principle, it's true that creep and impact are related, but they are quite different in degree, and are used differently in fuze mechanisms, so it's best to consider them separately.

Fuzes are operated also by more conventional energy sources.

Time fuzes for larger caliber projectiles are driven by springs, because the relatively slow rotation of these projectiles doesn't produce enough centrifugal force to run the clockwork reliably. Older time fuzes (no longer in use) consist of slow-burning powder trains of adjustable length, rather than clockwork. The powder is initiated by setback, which drives a firing pin into a percussion cap.

Proximity fuzes in projectiles are miniature radio transmitters and receivers, powered by tiny battery cells. The cells are activated by setback. When the projectile approaches closely to a target, the radio waves sent out by the transmitter are reflected back to the receiver in sufficient strength to close a circuit that initiates fuze action.

Most projectile fuzes use a small detonating charge to set off the explosive train. These are DETONATING fuzes. Some fuzes, however, are called IGNITION fuzes because they are designed to produce a flame that will set off an explosive sensitive to flame (usually black powder).

Fuze nomenclature also often indicates the physical location of the fuze in the projectile (fig. 3–9). Thus we have POINT or NOSE fuzes, and BASE fuzes. (Fuzes in bombs and other projectiles may be located elsewhere, too.)

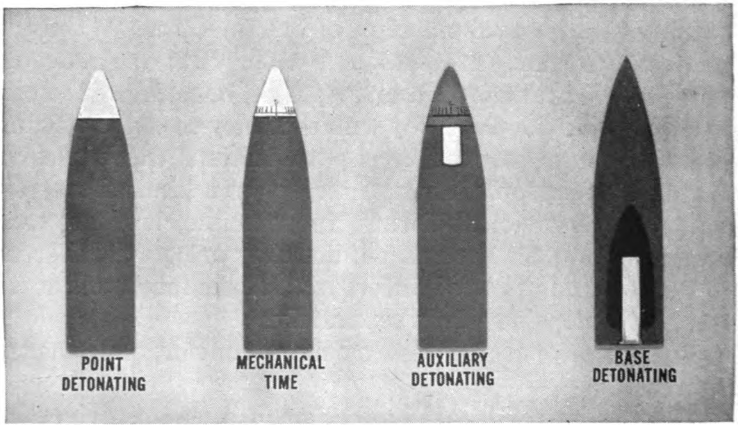


Figure 3–9.—Fuze locations.

In general, proximity, time, and percussion fuzes are in the projectile nose. Auxiliary detonating fuzes are located just behind the nose fuze. In AP projectiles (in which the hardened cap makes no provision for fuzes), the fuze is in the base. In some projectiles, like AA common, the time fuze in the nose is likely to fail on impact with even light armor, so the projectile has also a base-detonating (impact) fuze in the base.

A fuze is intended not only to explode the burster charge at the right time; it is intended also to PREVENT explosion at the WRONG time. A fuze is ARMED when it is made ready to function. When (as for example, before firing) it is set so as NOT to function, it is SAFE.

Fuzes have safety features to protect those who handle ammunition. These safety features may be put out of action by the time the projectile reaches the enemy. Some of the features are canceled by hand or mechanically before the gun is loaded. Others depend on the forces developed by the actual firing to arm the fuze. Fuzes that are armed only after the projectile leaves the gun muzzle are called BORESAFE. Projectiles 40-mm and larger are usually boresafe; projectiles 20-mm and smaller generally are not. This is important for you to remember when handling smaller caliber fuzed ammunition.

PYROTECHNICS

PYROTECHNICS is a Greek word for fireworks. The Navy uses fireworks not for celebration, but for illumination, screening, and signaling. An example is the ILLUMINATING PROJECTILE or star shell (SS) used to illuminate targets for gunfire, which was described earlier in this chapter. This is actually a pyrotechnic device, even though it is encased in a projectile body of standard external shape, and is fired from a standard rifled gun.

In the following sections we shall take up pyrotechnics launched by hand or from special projectors, or simply held by hand. All the pyrotechnics we shall study here are intended for signaling.

The Navy issues pyrotechnics not only for use aboard its surface combat ships, but also for use by aircraft, submarines, motor torpedo boats, and merchant ships, as well as for use ashore. However, we can here discuss only those issued as SHIP'S PYROTECHNICS. For the others see the OP on pyrotechnics (at present OP 1177).

The pyrotechnic units we shall take up are—

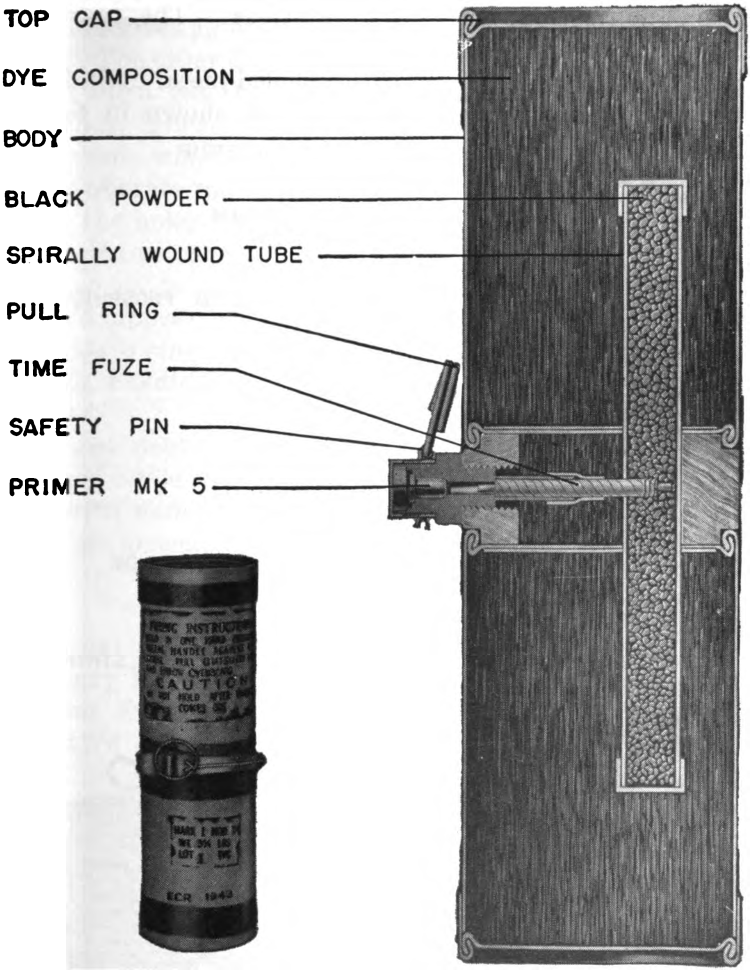
1. Depth charge markers.
2. Signal lights, and the pyrotechnic pistols and projectors used in firing them.
3. Distress and hand signals.
4. Navy lights.

Depth Charge Markers

Depth charge markers are of two general types—those for day use (Mk 1 Mod 3) and for night use (Mk 2). The marker for daytime use spreads a patch of bright yellow dye on the water; the night type burns with a yellow flame for 45 to 55 minutes. Both types are used to indicate the point of discharge of depth charge barrages and to provide a reference point for further antisubmarine attack. (A Mk 1 Mod 2 marker, still occasionally used, has green dye.)

The depth-charge marker Mk 1 Mod 3 (fig. 3–10) is a cylindrical waterproofed container about 12 inches long and 3.5 inches in diameter. When you pull the ring attached to the safety pin and release the safety lever, the primer ignites the time fuze. Fifteen seconds later the black-powder charge bursts the two dye containers and scatters the dye. The marker is dropped about 25 yards from the actual point where the depth charge itself was launched, so that the depth charge's "boil" when it bursts will not dissipate the slick of dye. Never pull the pin until the marker is to be launched. After the pin is pulled, keep the safety lever firmly against the marker body until it actually leaves your hand.

WARNING: If the marker is accidentally dropped after the pin has been pulled, clear the area. DON'T try to re-



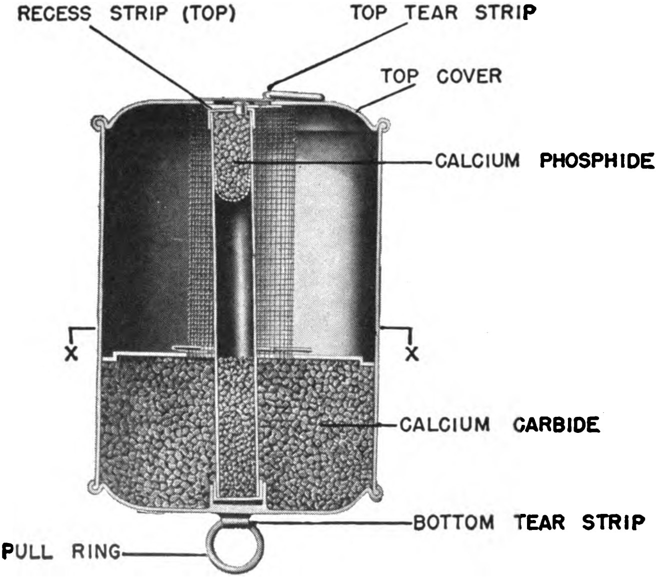
FULL VIEW SECTION VIEW

Figure 3–10.—Depth charge marker Mk 1 Mod 3 (day).

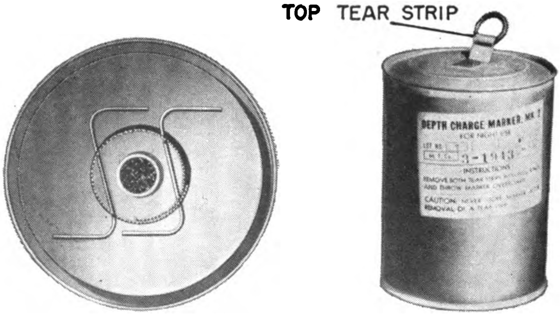
trieve the marker and make it safe again; it cannot be done.

If exposed to moisture, the dye in the marker cakes and doesn't spread very well in the water. The markers should, therefore, be kept dry.

The Mk 2 (night) marker is a sealed metal cylinder 7 inches high and 5 inches in diameter, shown in figure



SECTIONAL VIEW



SECTION X-X

FULL VIEW

Figure 3–11.—Depth charge marker Mk 2 (night).

3–11. It contains two chemicals. One of them is calcium carbide, the stuff that was used back in the horse-and-buggy days for carriage lamps. When wet, calcium carbide gives off acetylene, a gas that smells evil but burns well. The other chemical (calcium phosphide), when wet, gives off a gas that ignites by itself, without help from matches, ignition charges, or the like. This ignites the acetylene, which burns with a white flame.

To operate the marker, pull the rings on the marker to open the holes which allow water to get to the chemicals. Then throw the marker overboard, allowing a short time lag, so as to avoid the depth charge "boil." The flame should appear in 45 to 50 seconds. DON'T remove the tear-strip rings until ready to cast the marker overboard. NEVER handle or carry the markers by their tear-strip rings.

Night depth charge markers (Mk 2) should be inspected while in stowage for damaged tear strips. Markers with damaged strips should be disposed of immediately as unserviceable.

Signal Lights

Signal lights, often called Very lights (not because they are very light, but because that is what they were called by the French, who originated them), are similar to standard shotgun cartridges in appearance. When fired from the proper pistol or projector, a burning star (somewhat like a star from a Roman candle) shoots high into the air, as shown in figure 3–12.

The Mk 2 signal light is available in three colors—RED, GREEN, and WHITE. Each cartridge has a percussion primer and a propelling or expelling charge of ten grains of black powder, which projects the burning star to a height of about 200 feet. The star charge is a tightly packed cylinder wrapped with a quick match (a fast-burning fuze), which ignites it when fired. The star charge is separated from the expelling charge by a shock-absorbing wad of hard felt. The cartridge is closed by a wad which

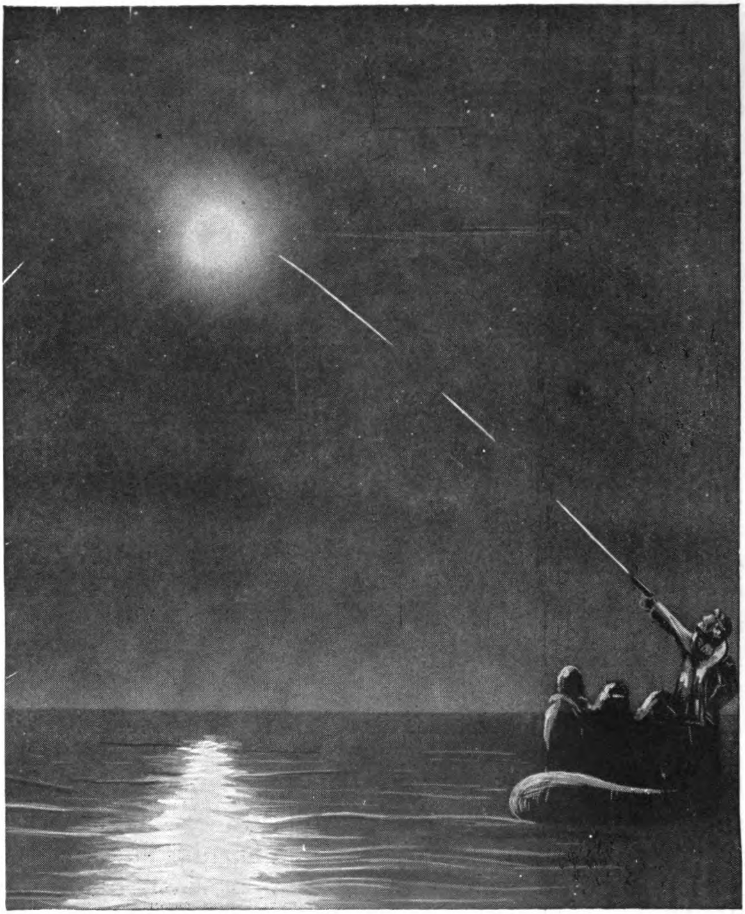


Figure 3–12.—Projected signal light.

is marked so that the color of the star can be determined by feeling it, as shown in figure 3–13.

The RED star may be identified by its corrugated closing wad. It burns for approximately 7 seconds.

The GREEN star has a smooth closing wad. It burns for approximately 5 seconds.

The WHITE star, which burns for approximately 6 seconds, has a small conical boss on its closing wad.

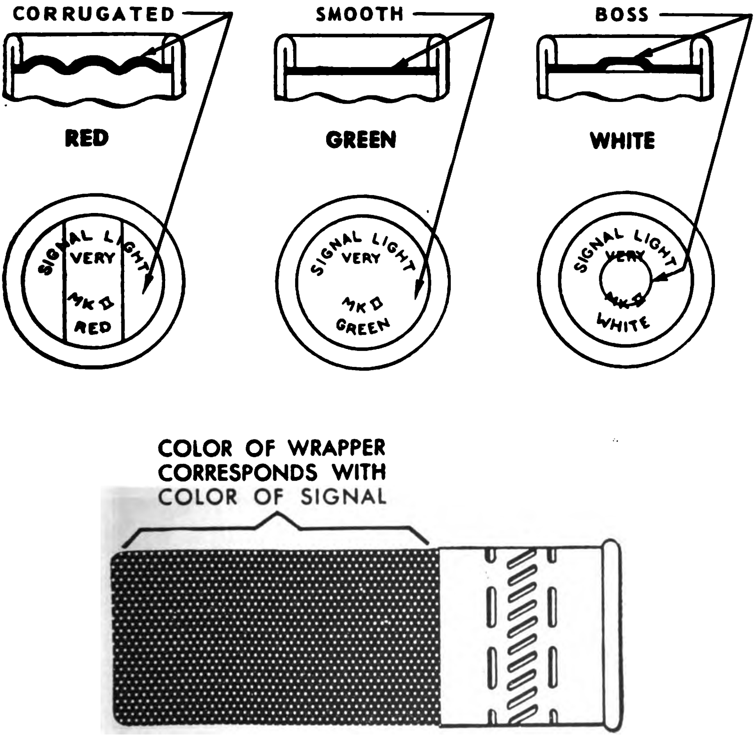


Figure 3–13.—Markings on signal light Mk 2 Mod 0 (Very light).

Each of the three colors is also identified by the corresponding color of the paper on the cartridge.

The lights are available in combination kits known as Service Box, Signal Pistol Mk 5; and Reserve Box, Signal Pistol Mk 5. Unless packed in kits, signal lights are packed in a metal can in units of ten; and 100 cans, or 1,000 signals, are packed in a wooden case for shipment purposes.

Signal lights are fired from the signal pistol Mk 5.

Signal pistol Mk 5, for use with signal light Mk 2, is a single-barrel, breech-loading pistol, 11 inches long. Metal parts are mounted on a plastic frame. A cartridge belt

(Mk 1) and holster are issued for use with the pistol. Figure 3–14 shows how to use the pistol.

1. To load the pistol, depress the latch button below the barrel. At the same time pull the barrel downward, as in part A of the figure. Then insert the signal light shell (as in part B of the figure). Push the barrel upward again until it latches closed. The pistol is now ready to fire.
2. To fire the pistol, aim it upward at the desired angle, but clear of other ships or personnel. Pull the trigger, as shown in figure 3–14C. Keep your elbow slightly bent when firing, to absorb the shock of recoil without having the pistol knock itself out of your hand.
3. To extract the expended shell, break the pistol open again as in step 1, and pull it out of the chamber, as in figure 3–14D.

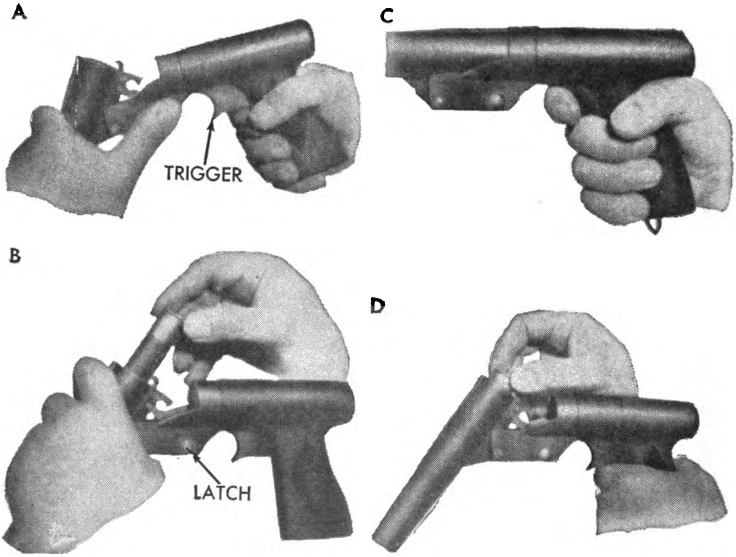


Figure 3–14.—Operation of signal pistol Mk 5.

Signal pistol Mk 5 must be kept in serviceable condition at all times. Clean it thoroughly after each time it is used. Wipe down all parts with a cloth impregnated with light machine oil. After assembly, wipe the exposed parts with a dry cloth. Swab the barrel with a cloth dampened with acetone or other solvent to remove powder residue.

When loading or firing pyrotechnic pistols, NEVER point them in the direction of other personnel or vessels.

NEVER use signal pistol Mk 5 with ammunition other than that authorized for use with it. Conversely, signal lights should never be fired from shotguns, or from projectors other than those authorized.

Distress Signals

There is something Biblical about the distress signal Mk 13 Mod 0. Like the famous pyre in *Exodus*, it provides by day a pillar of smoke, and by night a fiery light. It's a mighty comforting thing to have in a life raft or life vest.

The Mk 13 Mod 0 signal (fig. 3–15) is a metal cylinder about 5⅛ inches long and 1⅝ inches in diameter. It weighs between 6 and 7 ounces. One end contains a canister which, when ignited, produces orange smoke for about 18 seconds. The other end contains a pyrotechnic flare pellet which will burn 18 to 20 seconds.

Each end of the metal tube is enclosed by a soldered cap with a pull ring through which you can put your

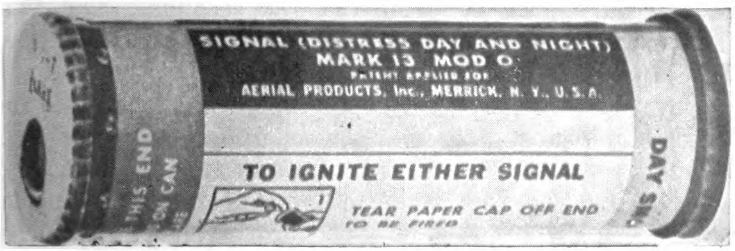


Figure 3–15.—Distress Signal Mk 13 Mod 0.

finger. When you pull the cap loose, a brass wire attached to its inside surface moves through a cap coated with a composition that ignites by friction, setting off either the flare or the smoke canister (depending on which ring you pull). The metal caps of the signal are covered with paper when issued; you must remove the paper before the pull rings are accessible.

The signal body carries illustrated instructions for use. The flare end has embossed projections extending around the case to identify it as the right end to use at night. When you use the signal, point it away from the face and hold it at arm's length at a 30° angle after it ignites. After one end of the signal has been used, douse the signal to cool the metal parts. Keep it so that the other end can be used if necessary. Each end is separately insulated and waterproofed. NEVER try to use both ends at once. When using the smoke signal, keep it windward.

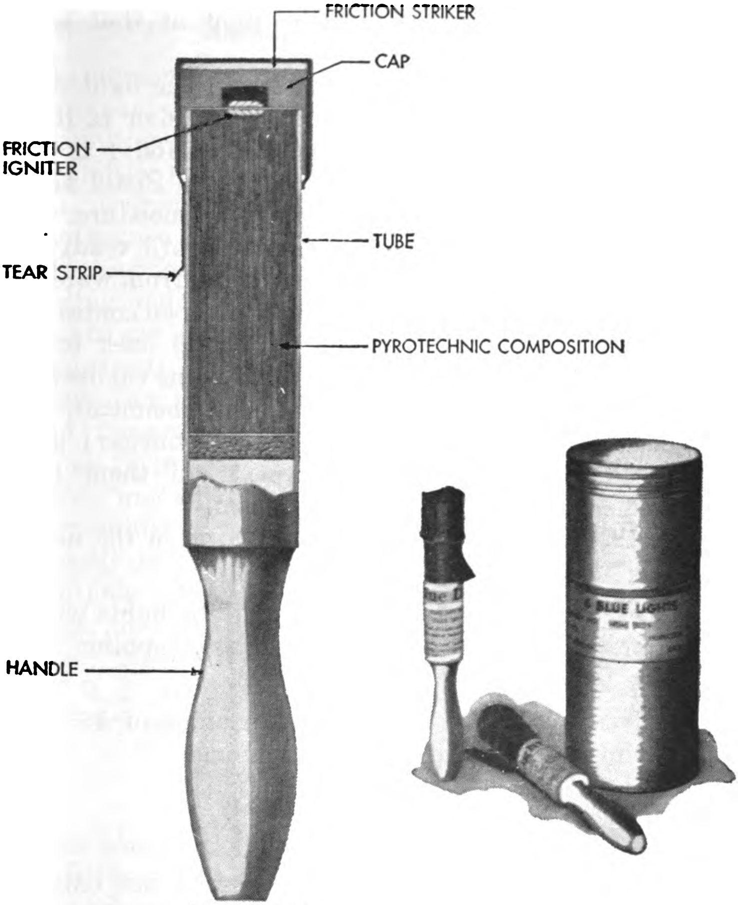
These signals are shipped in wooden boxes containing 100 units, and are also available in metal cans containing four units, for stowage in life boats, floater nets, etc. Avoid rough handling. Stow in a cool, dry place, in accordance with standard pyrotechnic stowage rules.

Navy Lights

Navy lights are hand torches which burn with a brilliant light visible at night up to 3 miles away. They come in two colors, blue and red. Navy blue light Mk 1 Mod 1 burns between 60 and 90 seconds; Navy red light Mk 1 Mod 0 burns between 150 and 180 seconds. The two lights are similar in appearance and construction (fig. 3–16).

Navy lights consist of a paper tube, which contains the pyrotechnic substance, with a wooden handle at one end, and at the other end a cover with an exterior coating of abrasive like that on the scratching side of a safety match box. A tear strip protects the cover's exterior.

The upper end of the paper tube, beneath the cover, is



Sectional View

Figure 3–16.—Navy lights.

capped by a fabric impregnated with igniting compound similar to that on the head of a safety match.

To ignite the Navy light, tear off the protective strip, remove the cover, and scrape the inverted cover across the top of the paper tube. When you do this, it's advisable to hold the light pointing AWAY from you at an angle of about 45°, to avoid contact with hot particles falling off the pyrotechnic candle. Hold the light at that angle throughout the burning.

Navy red light Mk 1 Mod 0 and Navy blue light Mk 1 Mod 1 are shipped in metal containers with 6 or 12 lights packed in each. Navy blue light Mk 1 Mod 1 is also shipped as part of the Reserve Box, Signal Pistol Mk 5. These lights deteriorate when exposed to moisture. Do not remove them from their containers until ready for use. For the same reason, keep them away from water or moisture. Lights which have been left in open containers for more than 6 months should be turned back to the nearest ammunition depot or magazine at the earliest opportunity. Lights which have become chemically encrusted, or which give off an acetic acid (vinegar) odor, should be immediately disposed of. Put them in a weighted sack and dump them overboard.

Note the following SAFETY PRECAUTIONS in the use of Navy lights:

1. Select carefully the place at which the lights will be burned, because burning particles dropping from the lighted candles can start fires.
2. Always hold the light up at an angle of 45° and point it to leeward while it's burning.

Pyrotechnic Kits

Very lights and hand lights are issued not only by themselves but also as kits. These kits are those assembled around the Mk 5 signal pistol. The Mk 5 signal pistol SERVICE BOX contains two pistols, a set of spare parts for the pistols, two holsters, a cartridge belt, and 50 each of red, white, and green cartridges, all assembled in a metal box. The Mk 5 signal pistol RESERVE BOX contains one pistol with spare parts, two Navy blue lights, and 50 each of red, white, and green cartridges. These kits are the ones you can most commonly expect to find aboard ship.

AMMUNITION MAINTENANCE

Maintenance of ammunition is rather different from maintenance of equipment. You don't have to lubricate ammunition (with one outstanding exception—20-mm ammunition), change its hydraulic fluid (because it hasn't any), or exercise it to see if it's working. Ammunition maintenance is a matter of keeping it securely stowed, protecting it from moisture and high temperatures, inspecting and testing it to make sure the explosive components are in safe condition, and cleaning it as required. The process of inspection, testing, and maintenance of ammunition has a long name of French origin that you'll often come across—SURVEILLANCE. (Don't try to pronounce it in French, though; "sir-VALE-ance" is good enough, unless you're talking to a Frenchman.)

Ammunition stowed under favorable conditions will normally last a long time without serious deterioration. Favorable stowage conditions include moderate temperatures, adequate ventilation, and absence of moisture and water. Nevertheless, ammunition being the destructive stuff it is, regular frequent inspection and testing are necessary no matter how favorable the conditions seem.

GUN PROPELLING CHARGES

Smokeless Powder Stowage

The ammunition component that gets the most watching is the smokeless powder in the propelling charge—particularly powder based on nitrocellulose (pyro powder). The reasons it needs watching are two:

1. Pyro powder contains ether and alcohol, both of which are highly VOLATILE—that is, they evaporate exceedingly easily. If the powder loses much of them, it tends to burn too fast and too irregularly when fired. The changed burning rate throws the initial velocity off from the prescribed figure (which messes up the fire control calculations); moreover, the change is erratic, and is difficult to predict and correct for. Besides, the erratic burning rate is

hard on gun mechanisms, which are not designed for this kind of variation.

2. The main component of pyro powder—nitrocellulose—is not absolutely stable. It tends to break down chemically, and this breakdown produces corrosive gases which themselves tend to hasten the breaking-down process still more. To reduce deterioration, the powder factory adds a chemical stabilizer called DIPHENYLAMINE, which reduces the rate of break-down by absorbing its products, but it does not put a full stop to the process.

To retard deterioration as much as possible, smokeless powder must be—

1. Stored in AIRTIGHT, WATERTIGHT containers. This not only slows up evaporation of volatile components of the powder, but protects the powder from water. That's why powder tanks are airtight and watertight, and why it's so important that they be kept that way.
2. Protected from unfavorable TEMPERATURES. If you've ever operated an automobile with alcohol-type antifreeze in warm weather, it's no news to you that volatile substances evaporate faster in high temperatures. By the same token, propelling-charge storage temperatures are best kept low. The ideal temperature is 60° Fahrenheit. The magazines on your ship, however, are likely to be a great deal warmer than that most of the time. When the temperature gets up around 90° F, it will be up to you to do something about it, because prolonged exposure to that kind of temperature makes smokeless powder very dangerous. That's where ventilation systems and blowers come in handy.

Besides this, the powder must be periodically INSPECTED and TESTED to keep a check on it. Moreover, the magazine itself must also be periodically inspected.

Now let's see how these requirements are put into effect aboard ship.

Since magazines are not common cargo spaces, but are designed for storage of smokeless powder, they are especially adapted for the purpose. They are protected by their location in the ship, and are insulated against moisture and excessive heat. Besides, they are equipped with sprinklers for protection against fire and possible explosion, as well as for emergency cooling. And they may be equipped with power blowers and refrigerating machinery in addition to provisions for natural ventilation.

Power ventilation helps prevent excessive temperatures, dampness, and "sweating" (condensation of moisture on bulkheads and deck). But always make sure that the air being supplied is cooler and drier than the air being exhausted. Sometimes the best way to keep the magazine cool and dry is to secure ventilators. Consider tropical and semitropical regions, where it gets exceedingly hot in the daytime but gets cool at night. In such circumstances, running the blowers all night but securing them for the day at about 0800 might be the best practice.

Proper stacking of powder tanks is important for best ventilation. The interlocking rings of the tanks separate the tanks enough for free circulation of air around them. The stacks must be clear of the bulkheads, as provided for by the stowage fittings.

No matter how effective the magazine's insulation, no matter how big and powerful its blowers, the only way you can be SURE of safe powder stowage is by routine effective inspection and maintenance of the magazine, and by routine effective inspection and testing of powder.

The magazine is intended for storage of live ammunition and authorized tools for handling it—and for these only. It's not the place for expended cartridge cases, empty powder tanks, drill ammunition grommets, cork plugs, unused dunnage, and similar odds and ends. It's especially not the place for stowing misfired ammunition, duds, or ammunition considered in dangerous condition, nor for stowing paint cans and brushes, oily waste rags, and similar fire hazards. And what goes for material also goes for men. Nobody but those authorized should ever be admitted to the magazine. Even they should be there only when they have business there. A magazine is no place to sit around to pass the time of day.

Magazine maintenance is chiefly a matter of inspections, cleaning, occasional painting, sprinkler testing, and repair and replacement of lights, fixtures, etc., as required. Magazines are inspected daily; other magazine work is done in accordance with the rules laid down by the gunnery officer, and will vary from ship to ship. Painting, by the way, is done when the magazine is empty.

When you inspect a magazine, you not only should look around; you should sniff around, too. If you detect an unusually strong smell of ether, alcohol, or both, it's likely to be the sign of a leaky ammunition tank. The thing to do is to locate the tank, pull it out of the magazine, and remove the ammunition. Turn the ammunition in to an ammunition depot as soon as possible. Have the defective tank repaired and report the matter as provided in the standing procedure set up for the ship.

Magazine Temperature Checking

However, there's more to testing powder than running your nose around the corners of the magazine. The main item of daily routine inspection is to check the most important single factor that affects powder stability—the temperature—and record it.

To check the temperature, you need a thermometer, of course. But an ordinary thermometer won't be enough. Temperature readings are customarily taken in magazines only once a day. The common type of thermometer tells you what the temperature is at the time you read it. But what was it when you weren't around? You need a thermometer which can record the HIGHEST temperature reached up to the time the reading was taken.

You'll find on the magazine bulkhead, therefore, a

MAXIMUM-MINIMUM THERMOMETER (fig. 3–17). This instrument is a U-shaped mercury-filled glass tube with two bulbs. It shows the extreme temperatures, both high and low, indicated since the thermometer was last ZEROED.

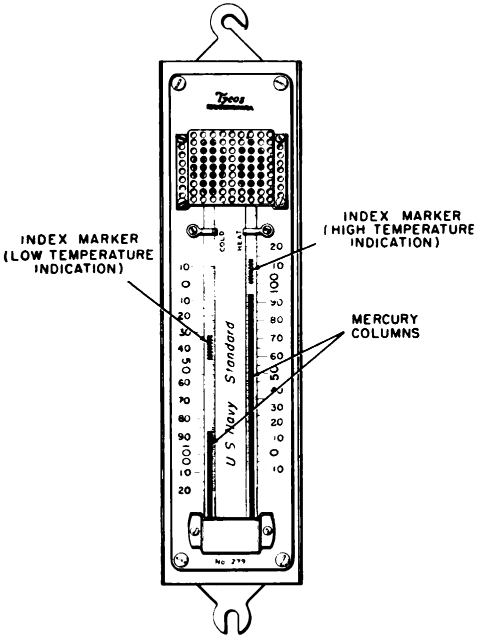

INDEX MARKER (LOW TEMPERATURE INDICATION)
INDEX MARKER (HIGH TEMPERATURE INDICATION)
MERCURY COLUMNS
Tycos
COLD
HEAT
US Navy Standard
No 279

Figure 3–17.—Maximum-minimum thermometer.

You read the PRESENT TEMPERATURE on the instrument by noting the level in either arm of the tube. (Both sides should read approximately the same.) The temperature recorded in the pictured instrument is around 95°, which would call for some drastic action if it were actually on a magazine bulkhead.

You read the MAXIMUM TEMPERATURE by noting the level of the BOTTOM edge of the little steel index marker against the right-hand scale, which increases UPWARD. (The picture shows it at just over 100°, another excessive temperature, for a magazine.)

You read the MINIMUM TEMPERATURE (here a little over 45°), similarly, on the left-hand scale against the bottom edge of the little steel marker. The minimum scale increases DOWNWARD.

To zero the instrument, you run a little horseshoe magnet against the glass tube to draw each steel index marker down to the level of the mercury. Zero the thermometer on both sides AFTER you have recorded the maximum and minimum readings.

Magazines are usually equipped with two maximum-minimum thermometers—one in the coolest part of the magazine, and one in the warmest. Others may be used where it is considered necessary to have additional data on parts of the magazine that may get too warm—bulkheads near steam lines, for example.

Since powder, under usual stowage conditions, deteriorates continuously, even if slowly, it will eventually become dangerous. It's just a matter of time—fortunately, a good long time, under normal circumstances. But temperature readings are not enough for keeping track of the powder's stability. We need records of the powder's age and chemical characteristics, and we must keep the powder continuously under test to verify its condition.

Powder Indexes and Samples

Powder is manufactured in large batches, or LOTS. After proof testing and acceptance of the powder, a lot (or a blend of several lots) is designated as an INDEX, and is given an INDEX NUMBER. The index number identifies the index and roughly indicates its age. The chemical composition and ballistic characteristics of the index are kept on record by the Bureau of Ordnance.

When the ammunition depot normally issues powder to a ship, it attempts to issue all the powder for each caliber gun from a single index. Thus, if possible, all 6-inch powder for a light cruiser is from one index; all 5-inch powder for the ship is from one index, and so on. This system ensures that the propelling charges for all guns of a given caliber are ballistically uniform, and that the life of the powder in each charge will be about the same.

One index for each caliber on any one ship is an ideal. Like many other ideals, it is not easy to realize in practice. So you will often find, when you look into a ship's magazines, two or even three indexes for each caliber.

When you can't attain an ideal 100 percent, you get as close to it as you can. Therefore it is up to the Gunner's Mates in charge of the magazines to stow propelling charges of different indexes in such a way that they can be kept separate. If you can possibly avoid it, never mix indexes during firing. With some forethought and planning, you'll find that one index-one firing is an ideal that you can attain.

With each index the ammunition depot supplies two samples of the powder in the index, separately packed. They are the REPLACEMENT SAMPLE and the MAGAZINE SAMPLE. The samples are used for the two kinds of test—violet paper test and surveillance oven test—that are regularly run on the powder to check its stability.

These samples are not supplied with case ammunition having CRIMPED cartridges. Crimped ammunition in general now includes all fixed ammunition, and all semifixed ammunition with plastic plugs.

Powder Testing

The primary test of powder stability is the surveillance oven test. In this test, a small quantity of powder of the index to be tested is put into special stoppered glass bottles and goes into an electrically heated SURVEILLANCE OVEN. Controls maintain the temperature at 65.5° Centigrade (approximately 150° on the Fahrenheit scale). The principle of the test is that at a known high temperature the powder will deteriorate at a high rate; the length of time it lasts in the oven before giving off the telltale red fumes that mean complete deterioration will indicate its stability under magazine storage conditions. The test result is expressed in terms of the number of days the powder lasts before deterioration. Powder of excellent stability will withstand an oven test of 60 days or more.

You will not be expected to conduct the surveillance oven test, though you should know the principle of the test, how the test result is expressed, and what the red fumes mean. Your chief is the man responsible for running the surveillance oven test. Any work you do in connection with it will be under his close supervision.

Destroyers and other smaller ships are not equipped with surveillance ovens. Moreover, the oven test should be supplemented by some testing method that gives a continuous visible indication of powder stability under normal magazine conditions. That's why the Navy uses the VIOLET PAPER TEST.

The principle of the violet paper test is that the fumes produced by decomposing smokeless powder, even when these fumes are so weak as to be invisible, will bleach a strip of paper colored with a certain violet dye. In performing this test, a small amount of the powder to be tested and a strip of paper containing a specific strength of dye are sealed in a glass bottle as shown in figure 3–18. Note in pencil on the paper the date the test is started. The bottle should be protected from sunlight and stowed in the warmest part of the magazine, but usually a special

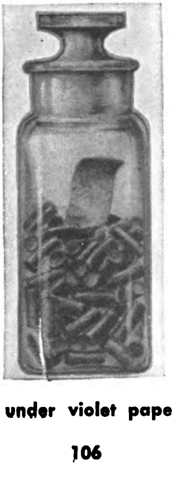


Figure 3—18.—Powder under violet paper test in sample bottle.

rack is provided. The test is required on all ships, but on ships with no surveillance ovens three samples of each index should be under test at all times.

As in the oven test, the violet paper test result is measured in the number of days required for the violet paper to bleach out. This will, at ordinary magazine temperatures, with powder in serviceable condition, require at least two months, and most probably much longer. There have been cases in which the test has run continuously for years. However, if there is a noticeable change in color within two months, the powder will require closer watching, and another sample bottle should be started.

In reporting the progress of the violet paper test, record the number of days since the date the bottle was started. If the paper still has color, add a plus (+) after the number to show that the test is still going on. If the paper is white, omit the plus sign. Check the color of the violet paper in a good light. Never open the bottle while the test is going on.

Though the violet paper and surveillance oven tests are the most sensitive methods of checking on powder stability, there are others—less sensitive, but much more direct. Your nose comes in handy here. If you open a powder tank or test bottle and smell the characteristic pungent odor of nitrous fumes, you have badly decomposing powder on your hands. Be careful, though, not to confuse the normal ether-alcohol odor of powder in good condition, or the vinegary (acetic acid) odor of powder that is old but still good, with the nose-searing pungency of nitrous fumes. Experience will teach you the difference.

Another characteristic of badly decomposed powder is the appearance of fine cracks in the normally smooth surface. As the powder continues to break up the originally smooth, hard surface of the powder grains, they become friable; that is, they crumble easily. Eventually they become mushy, and when that happens, the powder must be disposed of at once.

When you open a container of powder suspected to be in an advanced stage of decomposition, look for red nitrous fumes. This is another indication that powder deterioration has gone very far, and that the ammunition is dangerous. When you see the fumes, you'll have no trouble smelling them, or seeing the white or green corrosion that they cause in metal containers.

WARNING: Any of these indications of deterioration that you smell or see is an IMPORTANT DANGER SIGN. Don't fail to call it to the attention of your chief or of the gunnery officer.

SPCG

As has been stated earlier, the test methods and symptoms of deterioration that have been described apply to smokeless powder based principally on nitrocellulose (pyro powder) with diphenylamine stabilizer. SPCG, however, though it does contain nitrocellulose, contains even more nitroguanidine—which is itself stabler stuff—and has a different stabilizer (carbamite). It deteriorates much more slowly than pyro powder, and is more resistant to the effects of heat. Moreover, when it does decompose, it doesn't decompose in the same way, and because some of its products of decomposition are different, it must be tested differently.

At the present time, SPCG is subjected to violet paper tests much as pyro powder is, but, because of these differences, it may bleach N/10 paper even when it's perfectly safe. It's also tested in surveillance ovens, but the procedure is different. (For more detail on this, see the Navy training course *Gunner's Mate 1 & C*, NavPers 10186.)

Records of Magazine Inspections and Powder Tests

Like other maintenance procedures, magazine inspections and ammunition surveillance operations are performed periodically according to a prescribed schedule. The magazine inspections and surveillance operations at present prescribed for all United States naval vessels are as follows:

DAILY: Examination of powder magazine samples and violet paper strips. Taking readings on thermometers. Checking general condition of magazine—cleanliness, ventilation, lighting, presence of authorized tools and gear.

WEEKLY: Testing sprinkler system.

BIWEEKLY: Examination of replacement samples for signs of decomposition or change in appearance.

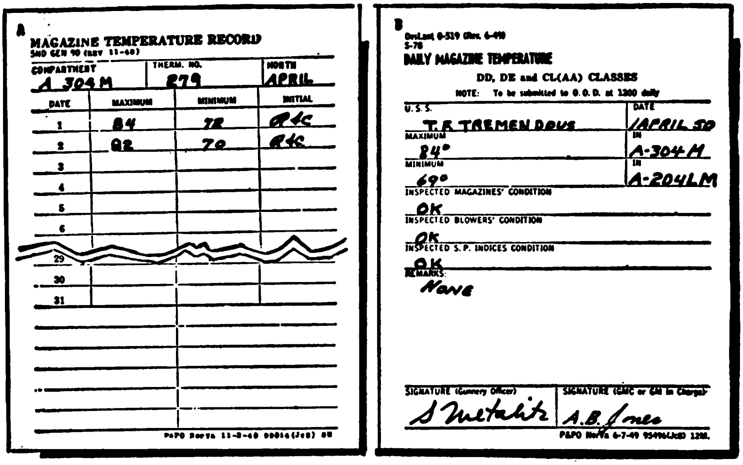
MONTHLY: Examination of one or more charges of each index for signs of decomposition or change in appearance. Samples of powder required for surveillance testing are taken in the course of this inspection. No monthly inspection is made of crimped case ammunition.

BIMONTHLY, QUARTERLY, SEMIANNUALLY: The only tests that take place regularly at long intervals like these are surveillance tests, with which you will not, as a GM 2, have much to do.

As you will find when you study the chapter in this course on ordnance maintenance, written records must be kept of all maintenance operations, whether they are routine or not. As far as magazine inspections and ammunition surveillance are concerned, the two most common written records that you as Gunners Mate or striker will be expected to keep are the MAGAZINE TEMPERATURE RECORD and the DAILY MAGAZINE TEMPERATURE form. These are illustrated in figure 3–19.

The magazine temperature record is a card posted in each magazine. On it you enter every day the maximum and minimum temperatures recorded for the previous 24 hours in that magazine. The card is replaced every month, and the old one is turned over to the gunnery officer.

On the daily magazine temperature report are summarized the results of magazine inspections for the whole ship. This form includes not only spaces for entering the highest and lowest magazine temperatures, but also for reporting the condition of the magazines and their



A

MAGAZINE TEMPERATURE RECORD
SND GEN 90 (REV 11-40)

COMPARTMENT A 304 M	THERM. NO. 279	MONTH APRIL

DATE	MAXIMUM	MINIMUM	INITIAL
1	84	72	[illegible]
2	92	70	[illegible]
3			
4			
5			
6			
29			
30			
31			

P&PO Norva 11-8-40 [illegible]

B

DesLant 0-539 (Rev. 6-49)
S-78
DAILY MAGAZINE TEMPERATURE
DD, DE and CL(AA) CLASSES
NOTE: To be submitted to O. O. D. at 1200 daily

U. S. S. T. E. TREMENDOUS	DATE 1 APRIL 50
MAXIMUM 84°	IN A-304-M
MINIMUM 69°	IN A-204LM

INSPECTED MAGAZINES' CONDITION OK
INSPECTED BLOWERS' CONDITION OK
INSPECTED S. P. INDICES CONDITION OK
REMARKS: None

SIGNATURE (Gunnery Officer) S Metalitz	SIGNATURE (GMC or GM in Charge) A.B. Jones

P&PO Norva 6-7-49 95496(JcE) 12M.

Figure 3–19.—Magazine records. A: Magazine temperature record. B: Daily magazine temperature report.

ventilating device, for the violet-paper test indications of the condition of the various indexes of smokeless powder aboard, and (under REMARKS) for miscellaneous nondaily routine work like sprinkler testing. As the form indicates, the report is signed by the Gunner's Mate in charge and by the gunnery officer, and is submitted to the OOD daily before 1200.

The forms illustrated in figure 3–19 are those prescribed for destroyers under ComDesLant, but reports of this kind are required aboard all ships carrying ammunition, although the exact forms used may vary.

OTHER COMPONENTS OF GUN AMMUNITION

So far we have concentrated on gun propelling charges, which actually do require the lion's share of attention. But we do not neglect other ammunition details.

Fixed Ammunition

Unless you have specific permission of competent authority, the knowledge of how to do it, and the proper tools, you have no business disassembling fixed ammunition to obtain samples of propelling charges for testing. And you're not likely to have much occasion to do this. So treat fixed ammunition in accordance with the requirements of its explosive components, both smokeless powder (discussed above) and projectile contents (taken up later in this chapter).

As for small-arms ammunition, any tampering with it at all is forbidden. (Surveillance of small-arms ammunition is discussed in another chapter in this course.)

Primers for separate-loading ammunition

The main points to bear in mind about primers for separate-loading ammunition are that they are sensitive, and must therefore be handled with care; and that they must be stowed apart from the propelling charges with which they're used—and from all other ammunition, for that matter. The mercury fulminate that some of them contain is made less reliable in functioning if exposed to excessive heat. Keep them dry, too; moisture puts mercury fulminate practically out of business as an initiator. Lead azide is a little less critical, but in general the same principles apply.

Projectiles

The stowage requirements of projectiles containing explosive components are determined principally by those components. So let's take them up briefly.

Compared to smokeless powder, other explosives require little surveillance. However, though they may require less detailed examination and testing, other explosives can be even more dangerous in deteriorated condition. Close, regular inspection is just as important for them as for smokeless powder. Let's take up these explosives individually.

BLACK POWDER, in sealed containers or in ammunition, is relatively easy to store. Moisture, as we found in discussing it in the preceding chapter, is bad for it, so keep your black powder DRY. Dry, it will keep indefinitely without deterioration. Most ammunition contains some black powder.

A word about black powder in bulk: It is important to be sure that black powder containers are free from corrosion, holes, cracks, and other defects, and that they are tightly packed. Never open black powder containers in a magazine, or in the presence of other explosives. When you make up charges containing black powder, not more than one container of bulk powder and one of the containers being filled from it should ever be open at one time. Remove empty powder containers and fill them with water until they can be thoroughly cleaned. And use only nonsparking tools around exposed black powder.

TNT. After a considerable storage period, you will sometimes find that a brown, oily liquid dribbles out or EXUDES from ammunition filled with cast TNT. This EXUDATE is inflammable and fairly sensitive to percussion. Exudate does not cause the TNT inside the ammunition to become more dangerous; but the exudate itself is a form of TNT, and it is outside the TNT container, where it does not belong and where it is exposed to flame. Exudate is, therefore, a fire hazard as well as an explosive hazard, and must be removed as soon as it is detected.

If the exudate is relatively recent and has not had a chance to harden too much, you can safely remove it by diligent application of PLAIN WATER and a stiff nonmetallic bristle brush. Do NOT use soap, lye, washing soda, or other alkaline cleaning agents; they make the exudate more sensitive. Do not use a wire brush. Stubborn deposits will yield to carbon tetrachloride. However, because the fumes of carbon tetrachloride are dangerous to breathe, don't use it unless there is plenty of ventilation.

TNT exudate does become very dangerous when in contact with wooden decks, bulkheads, shoring, dunnage, and so forth, or with cotton or other fabric. It becomes highly sensitive to flame, and is much more risky than exudate in pure form. That is why ammunition containing TNT should not be stored on wooden decks or dunnage for any prolonged period, or where exudate may come into contact with wood or fabric of any kind.

Exudate forms more rapidly as the temperature goes up; TNT should, therefore, not be exposed to heat or direct sunlight. However, the only sure way to deal with exudate is by regular, careful inspection and cleaning.

MERCURY FULMINATE. We've already mentioned how this highly sensitive explosive, becomes LESS sensitive as the temperature goes up, and how moisture affects it. Since this may have a bad effect on the functioning of the fuzes, caps, primers, and detonators in which it is used, it requires protection from heat and wet. The same goes for LEAD AZIDE and other initiating compounds.

EXPLOSIVE D is very stable and requires no special testing on board ship. It does not form an exudate like TNT. Protection against high temperatures and moisture is all that is required. In case of fire in the vicinity of Explosive D loaded projectiles, sprinklers should be used to keep the projectiles cool, since they might otherwise explode because of the heat. This practice is a good one to apply to any projectiles so endangered.

TETRYL requires no special tests, and should be handled with the precautions used generally for other high explosives.

TORPEX, HBX, and RDX should be handled in the same general manner as TNT.

Pyrotechnics

In the preceding discussion of ammunition surveillance we have been mostly concerned with gun ammunition and the explosives found in it. In general, the same principles apply to pyrotechnics. Pyrotechnics and pyrotechnic ammunition (except illuminating projectiles, which are stowed with other gun ammunition of the same caliber) are generally stowed in cool, dry, well-ventilated magazines below decks but preferably above the water line, or in special pyrotechnic lockers located in the weather deck.

Storage temperatures should be kept down below 100° Fahrenheit.

Each type of pyrotechnic should be stowed separately from other types; where quantities are small (as is usually so), more than one type may be stored in a single compartment. With the single exception of illuminating projectiles, however, pyrotechnics are NOT to be stowed with other types of ammunition.

Signaling pyrotechnics for boats, life rafts, and other small craft are packed in watertight containers and stowed in the craft.

Stow smoke-making ammunition in dry, cool locations above decks. A fire in smoke-making ammunition is not easy to fight under any conditions, but is particularly difficult below decks. Pyrotechnic ammunition in general is more of a fire hazard than other types of ammunition. Some types set fire to themselves (SPONTANEOUS COMBUSTION) if exposed to moisture, high temperatures, or rough handling. Some types have match igniters; stow them so that they cannot rub against each other or against other objects. When pyrotechnics do ignite, their hot fire is difficult to extinguish, though liberal amounts of water will cool nearby material enough to keep the fire from spreading.

When possible, store pyrotechnics in the boxes or watertight containers in which they are supplied. If it is necessary to remove pyrotechnics from their boxes for ready service stowage, protect individual items against direct sunlight, excessive heat, moisture, and spray.

QUIZ

In each of the following questions, select the ONE best answer.

1. Which of the following details of a round of ammunition for a bag gun is never loaded into the gun chamber?
   a. Projectile
   b. Ignition charge
   c. Propellant
   d. Primer
2. Which of the following is lacking in a case percussion ignition primer?
   a. Bridge wire
   b. Percussion cap
   c. Ignition charge
   d. Black powder
3. The main function of the nose cap of an AP projectile is to
   a. prevent premature detonation of the fuze
   b. improve the ballistic performance of the projectile in flight
   c. cut through the armor plate of the target
   d. provide a means of screwing the windshield onto the projectile
4. The timing mechanism of a time fuze begins to function
   a. upon the projectile's impact with the target
   b. as the projectile approaches the target
   c. when the projectile is fired
   d. when the fuze is set by a fuze setter
5. Setback is caused by the
   a. initial acceleration of the projectile
   b. spin of the projectile in flight
   c. gradual slowing down of the projectile due to air resistance
   d. impact of the projectile with the target
6. The agent that ignites the Mk 2 depth charge marker is
   a. acetylene
   b. black powder
   c. calcium carbide
   d. calcium phosphide
7. The signal pistol is used with
   a. Navy lights
   b. depth charge markers
   c. Very lights
   d. distress signals
8. In the violet paper test, the principle of the test is that the fumes of decomposing powder turn
   a. red after a certain length of time in the surveillance oven

b. white paper violet after a certain length of time in the surveillance oven
c. violet paper white after a certain length of time in the magazine
d. white paper violet after a certain length of time in the magazine

9. Decomposing powder produces a
   a. strong acetic acid (vinegar) smell
   b. strong smell of nitrous fumes
   c. pungent ether-alcohol odor
   d. smell as of something burning
10. No monthly inspection is made of
    a. crimped case ammunition
    b. bag ammunition
    c. the sprinkler system
    d. magazine samples
11. The best way to remove TNT exudate that is not badly hardened is by scrubbing with
    a. plain water and a stiff nonmetallic bristle brush
    b. soap
    c. washing soda or lye
    d. steel wool

CHAPTER 4

HYDRAULICS AND HYDROSTATICS

HYDRAULICS, HYDROSTATICS, AND THE GUNNER'S MATE

In the Navy, hydraulic mechanisms and applications of hydraulic and hydrostatic principles surround you everywhere—and they surrounded you before you joined the Navy, too. City water systems depend on application of hydraulic principles, and the running water in kitchen and bathroom is controlled by hydraulic devices. Even your barber uses a hydraulic device to adjust the chair you sit in.

You don't get away from hydraulics and hydrostatics when you join the Navy. Think of the hydraulic steering gear, the hydraulic anchor windlasses, the hydraulic hoists and cranes, the hydraulic gear on airplane catapults, and the host of other hydraulic devices you find on your ship. And think especially of the hydraulic mechanisms that are particularly important to you:

1. Power rammers
2. Training and elevating gear
3. Recoil and counterrecoil systems
4. Ammunition hoists
5. Depth charge pistols
6. Underwater weapons generally

Although these applications differ widely in purpose, they all depend on the same hydraulic and hydrostatic principles. You'll find, too, that although some of these mechanisms may be fairly complex when taken as a whole, even a complex one is in reality a system composed of a number of relatively simple mechanical components. Once you grasp the principles and the components, all you have to do is understand how they work together, and you understand the workings of the entire system. And when you understand this, you are better equipped to operate, maintain, and repair the system.

In this chapter we shall take up the principles of hydraulics and hydrostatics, and some of the elementary devices that make up every hydraulic system. In the chapter following, we shall take up more complex applications that you as a Gunner's Mate should know about.

Because this course hasn't the space to function as an encyclopedia, much about hydraulics and hydrostatics that doesn't directly relate to the applications you study has been omitted. You can fill in the gaps by reading any good physics text, or by reading *Basic Machines* (NavPers 10624) and *Basic Hydraulics* (NavPers 16193). *Basic Machines* is very widely distributed in the Navy; *Basic Hydraulics*, which is designed specifically as a classroom text, may not be as easy to find aboard your ship or station. Ask your educational officer. To learn more details about specific ordnance hydraulic mechanisms, look up the OP's on the equipment of which they are part.

WHAT ARE HYDRAULICS AND HYDROSTATICS?

The words HYDRAULICS and HYDROSTATICS are both based on the Greek word for water. Today we have broadened the idea to include all liquids. Without getting too technical, we can say that hydraulics is the study of the physical behavior of all liquids in motion, while hydrostatics is concerned with liquids at rest. In studying their applications in naval ordnance, it's pretty hard to keep them separate. Since, for our purposes, it is not important to do so, we're not going to try. But before we begin to study applications, let's look briefly first at the behavior of liquids at rest, then at the behavior of liquids in motion.

Though the term "hydrostatics" may be new to you, earlier courses in this series have already introduced you to the basic properties of liquids. These, as you remember, are:

1. Shapelessness
2. Incompressibility
3. Transmission of forces in all directions.

Now consider a couple of the corollaries or byproducts of these ideas.

First of all, the shapelessness principle obviously means that liquids must be led from one location to another by channels or pipes. But the incompressibility principle equally obviously indicates that a liquid under pressure will overflow its channel, so pipes must be used in all systems that contain liquids under pressure. And, because the pressure is exerted equally in all directions, under the principle you have learned about as Pascal's Law, ALL parts of any continuous system containing liquids under pressure are subjected to that pressure. (Pressures in systems with liquids in motion are not the same as those that exist when the liquid is at rest, but the general idea still applies.)

In both open and closed systems, there will be pressure at the bottom of any vertical column of liquid, regardless of whether any other pressure is applied. That's simply a matter of gravity. Liquids have weight. What's above presses down on what's below. The higher the column of liquid, the higher the pressure. You can demonstrate this to your own satisfaction very simply by puncturing two or three holes, one above the other, in a tin can. Fill it with water, and watch the water spout out of the holes. At the bottom, where the pressure is greatest, the spout will be biggest. The spouts above will be smaller, with the topmost smallest (fig. 4–1). The greater the pressure, the bigger the spout. By the way, this demonstrates that Pascal's Law applies to pressure developed this way

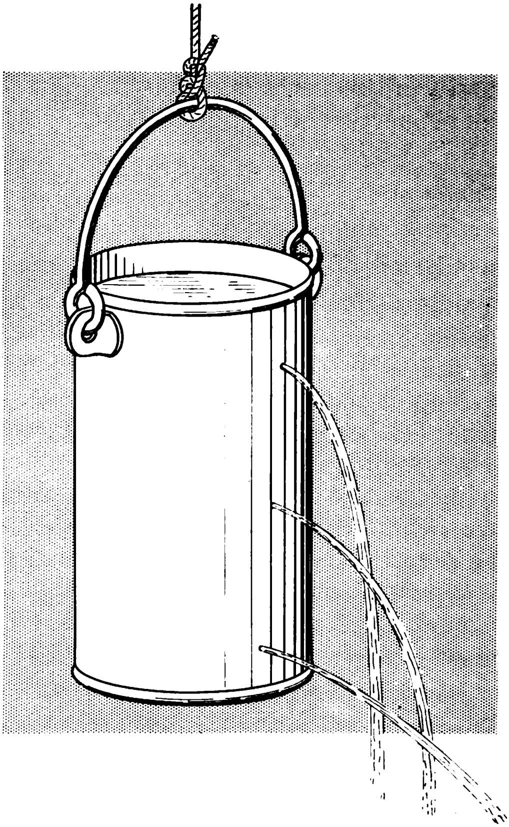


Figure 4–1.—Head depends on height.

too, because the pressure demonstrated by the spouts is exerted SIDEWISE, not downward.

This pressure is due to HEAD, which is measured here between the surface and the holes. It develops whether or not the liquid is in a "column"-shaped container. It exists in the open sea, and in the glass of beer you have in the evening. You can measure head as the vertical distance between any two levels in a body of liquid. It need not be measured (though it can be) between the surface (zero head) and the bottom (maximum head).

The pressure developed by head is measured in units of force (pounds, for example) per unit area. Thus we may speak of a head of 222 inches, which yields a pressure (or PRESSURE HEAD) of 8 pounds per square inch (psi). Not everybody observes this fine distinction between pressure and head, so don't be shocked to find head expressed directly in pounds per square inch or other pressure units.

Pressure head depends on the DENSITY of the liquid (that is, its weight per unit volume). Water, for instance, weighs 62.4 pounds per cubic foot. Oils are lighter; a typical oil weighs 55 pounds per cubic foot. Such an oil requires a head of 252 inches (as compared with water's 222) to produce an 8-psi pressure.

Let's distinguish now between PRESSURE and THRUST. Consider a cylinder in which is a freely movable piston. If we have on the right side of the piston a liquid under pressure at 1 psi, and the area of either side of the piston is 6 square inches, what would a scale connected to the piston at the left side register? Answer: SIX pounds. The PRESSURE is 1 psi, and it's exerted on every square inch of that side of the cylinder and piston. But the THRUST produced by this pressure on the 6-square-inch area piston is the pressure multiplied by the area, hence it's 6 pounds (fig. 4–2).

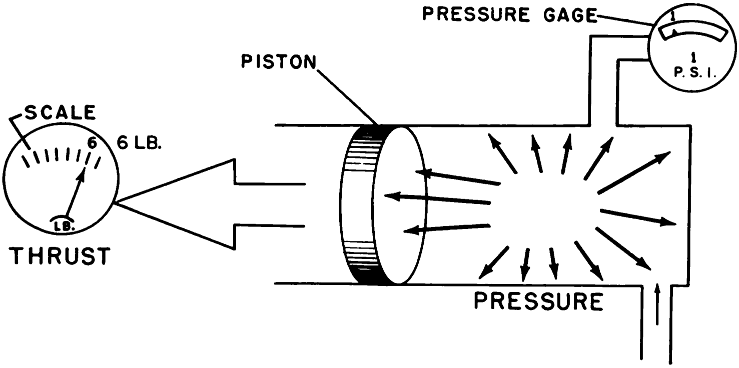


Figure 4–2.—Pressure vs. thrust.

Note that if there were LIQUID in the left end of the cylinder, it would be under pressure. What pressure would be developed? Think. You should come up with this answer: 1 psi. Remember the area of both sides of the piston is the SAME, hence a given pressure gives the SAME thrust.

Now let's elaborate our system a little. On the right side, we still have the cylinder's liquid contents under 1 psi pressure exerted in all directions, including the 6-square-inch movable piston (fig. 4–3). On the other side of the piston we now have a piston ROD of such a diameter that the left side area of the piston is now 4 psi. Now let's put a liquid in the left side of our system, and connect it to a pressure gage.

The total thrust exerted by the right side on the left is still 6 pounds. But now, in effect, the piston is but 4 square inches in area on that side. Think about it, and it will become clear that a thrust of 6 pounds exerted on

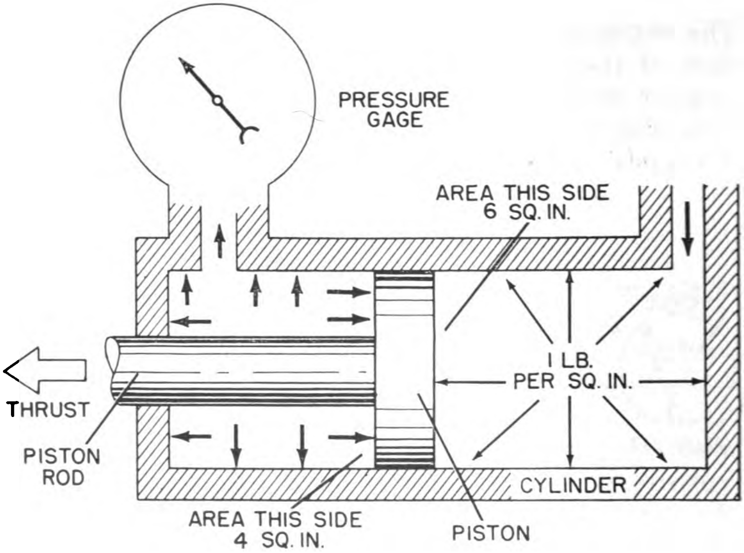


Figure 4–3.—Principle of differential area.

an area of 4 square inches will yield a pressure on the liquid in the left end of the cylinder of (6 divided by 4) 1.5 pounds per square inch.

This kind of setup is rather widely used in ordnance hydraulic systems, and is called a DIFFERENTIAL AREA CYLINDER. A piston rod isn't always used for changing area to give this result, though it does appear in many applications. Learn to recognize it when you come across it.

Pressure produced by an external force acting on an enclosed liquid is different from the effects of head produced by gravity. It does not depend at all on the density of the liquid, the amount of it, or its column height. It depends only on the magnitude of the thrust divided by the area of the liquid surface exposed to it. Thus a given thrust exerted on a small piston will produce a higher liquid pressure than the same thrust exerted on a larger piston. However, this does not apply to pressures directly produced by other fluid pressures. For example, if you open a 10-square-inch inlet into a closed liquid-filled tank from a liquid-filled system under 10 psi pressure, the pressure produced in the tank will be 10 psi,

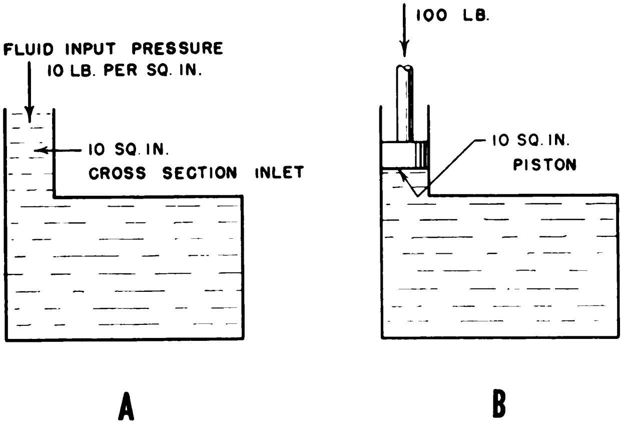


Figure 4–4.—The pressures in the two tanks are equal.

and will remain the same whether you enlarge or reduce the size of the inlet. (See fig. 4–4A.) But if you should substitute a piston of the same area (10 sq. in.) in the system, you would have to exert a thrust of 100 pounds to develop the same liquid pressure. (See fig. 4–4B.) Or you could reduce the piston area to 1 square inch and the thrust to 10 pounds to develop the same pressure.

Liquids in Motion

Up to this point, we have been considering hydrostatics—the properties of liquids at rest. In operation, however, most of the hydraulic systems we shall study involve liquids in motion. For this reason we must learn something about the fundamental properties of liquids in motion.

Let's begin with VOLUME OF FLOW and VELOCITY OF FLOW. By volume of flow we mean the QUANTITY of liquid that will pass a given point in a hydraulic system in a unit of time. Volume of flow can be stated in a number of ways, as, for example, 100 cubic feet per minute, or 100 gallons per minute, or per hour. Gallons per minute (abbreviated gpm) is the usual way of expressing volume of flow.

Velocity of flow means the RATE or SPEED at which the liquid is moving forward at a particular point in the system. It's usually stated in terms of feet per second (abbreviated fps).

Volume and velocity of flow are often considered together. With other conditions unaltered—that is, with volume of input unchanged—the velocity of flow goes UP as the size of the pipe DECREASES, and goes DOWN as the pipe size INCREASES. You've probably noticed that in a stream, velocity of flow will be slow at wide parts of the stream and rapid at narrow parts. The same thing is true in a hydraulic system. As the pipe narrows, velocity of flow goes up.

Note that in situations like this Pascal's Law doesn't apply rigidly. Where pipe diameter funnels down to a small value, fluid pressure tends to go up. Where the pipe broadens, fluid pressure tends to drop. The exact amounts of pressure changes depend on such factors as the velocity and turbulence of flow, the exact shape of the pipe, liquid density, and existing pressure in the system. But remember—this is true only WHILE THE LIQUID IS FLOWING. Once flow stops, Pascal's Law governs as before, and all applied pressures are transmitted equally in all directions.

In hydraulic systems, we're interested not only in rate of flow but also in the characteristics of the flow itself. Liquid flow may be either STREAMLINE or TURBULENT. In streamline flow (fig. 4–5A) the particles of liquid flow smoothly along with a minimum of interference and

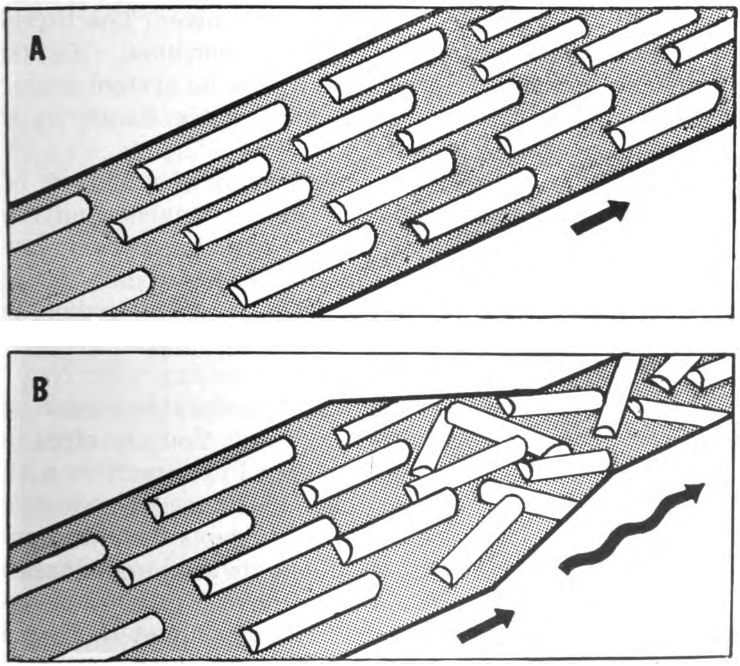


Figure 4–5.—Streamline and turbulent flow.

pretty much without colliding with each other. In turbulent flow (fig. 4–5B), on the other hand, the liquid particles interfere with each other; there are swirls, eddies, waste motion, and a general state of confusion. Turbulence wastes energy, and must be avoided as far as possible. To minimize turbulence, pipe should be clean and smooth on the inside, and should have as few bends as possible. Bends should be made on a radius of two and one-half to three times the inside diameter of the pipe.

The other important factors in liquid flow are INERTIA and FRICTION. You should already be familiar with these terms; if you're not, you'd better do some reviewing in *Basic Machines* (NavPers 10624).

One important effect of the inertia of a flowing liquid on a hydraulic system is WATER HAMMER. You get water hammer when flow in a pipe is too quickly interrupted, as, for example, by the hasty closing of a valve. The liquid rams forward, with the effect of a hammer blow. As you can well imagine, this places the hydraulic system under heavy strain. There's no mistaking water hammer; it causes loud, clanking sounds.

Although friction isn't as obvious in the motion of liquids as it is in the motion of solids, it exists and it's important. Its effect, as with solids, is to dissipate energy in the form of heat. Turbulence and friction go hand in hand. To minimize the effects of friction, hydraulic equipment is designed to keep it at the lowest possible level.

Friction of a liquid depends to a considerable degree on its VISCOSITY, or its resistance to flow. You are already more or less familiar with viscosity in connection with lubricants. It's because of the importance of reducing fluid friction in ordnance hydraulic systems that we mention viscosity here. The hydraulic fluids used in ordnance hydraulic systems are made up to have a minimum viscosity in order to reduce fluid friction, but at the same time they must function as lubricants. It's because of their delicate balance between these requirements, which are more or less contradictory, that the selection and use of hydraulic fluids is so careful a business.

BASIC COMPONENTS OF HYDRAULIC SYSTEMS

Not all hydraulic systems include all the essential components listed below, but no hydraulic system can function without at least some of them. They are:

HYDRAULIC FLUID, without which no hydraulic system can be hydraulic.

PIPE or TUBE LINES, to conduct the fluid to various components of the system.

VALVES, to direct and control the flow of hydraulic fluid, and to control fluid pressure.

GAGES, to measure pressure, velocity, and volume of hydraulic fluid at various points. (In ordnance hydraulic systems you are likely to find only pressure gages.)

PUMPS, to drive the hydraulic fluid through the system. (Naturally, you won't find pumps in systems where other means are used to drive hydraulic fluid through the system. An example of a pumpless hydraulic system is a gun recoil brake.)

BELLOWS, to register pressure increases by expanding as they fill with liquid.

ELECTRIC MOTORS, to drive the pumps. (Although steam or internal-combustion engines may drive pumps elsewhere on your ship, pumps in ordnance hydraulic systems are driven only by electric motors.)

WORK CYLINDERS and PISTONS, or HYDRAULIC MOTORS (which are, in ordnance hydraulic systems, usually combinations of work cylinders and pistons), to apply the energy furnished by the pump in order to do the work that the hydraulic system is intended to do.

RESERVOIRS and TANKS, to store hydraulic fluid. Under this heading we can also put PRESSURE CHAMBERS, to protect the system against shocks like water hammer; EXPANSION TANKS, to allow for expansion of the hydraulic fluid due to heat; and ACCUMULATORS to store hydraulic fluid under pressure for use in case of power failure or in case sudden heavy demand for fluid exceeds the capacity of the pumps. The chief difference between reservoirs and tanks on one hand, and accumulators and pressure chambers on the other, is that in accumulators and pressure chambers the prevailing system pressure is maintained; in the others, pressure is low or zero.

FITTINGS, to connect tubes and pipes and other components to each other.

GASKETS, to seal joints, and PACKING, to seal openings around moving parts, against leakage of fluid.

In this chapter we shall discuss only gages and valves. You studied pipes and tubes, fittings, gaskets, and packing in earlier Navy training courses in this series. Hydraulic pumps and motors are considered in the next chapter of this book. And for information on hydraulic fluids, see OD 3000.

GAGES

There are gages for measuring practically everything measurable about a hydraulic system. The types you're likely to encounter in connection with routine operation and maintenance of ordnance hydraulic systems are the BOURDON PRESSURE GAGE, and the SCHRADER PRESSURE GAGE.

Bourdon Gage

The BOURDON GAGE (fig. 4–6) is a very sensitive and accurate type of instrument; high-precision units are accurate to about 0.25 percent of full-scale reading. Like other sensitive accurate instruments, however, the Bourdon gage is far from rugged. It easily goes out of kilter when subjected to rapidly fluctuating pressures and to vibration.

The Bourdon gage works on the very simple principle that pressure in a curved tube will tend to straighten it out. The paper snake you blew into and uncoiled at your last New Year's party works on the same principle.

Behind the dial of a Bourdon gage is a relatively thin-

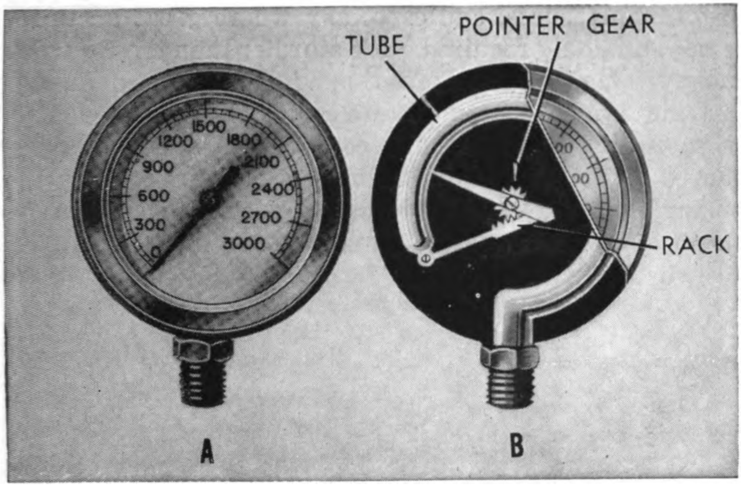


Figure 4–6.—Bourdon gage.

walled metal tube bent into a circular arc, as shown in figure 4–6B. One end of this tube opens into a fitting threaded for insertion into the system to be measured. The closed end is linked to a rack that engages a small gear wheel. A pointer is attached to the gear. Under pressure, the tube tends to straighten, moving the rack, which in turn rotates the gear and pointer. The greater the pressure, the more the tube straightens, and the further the needle turns.

Bourdon gages of all kinds need frequent resetting. They should be protected from vibration, excessive temperatures, corrosive fluids, and sudden high pressures. Pressure gages in general, and especially the Bourdon type, should not be kept permanently open to line pressure. When a reading is desired, let fluid into the gage by slowly opening the petcock or valve in the gage line.

Schrader Gage

Because of the relative delicacy of the Bourdon gage, you're more likely to see the Schrader gage installed wherever there's a good deal of vibration or rapid fluctuation of pressures, and especially where great accuracy is not absolutely required. It's sturdier than the Bourdon mostly because it has fewer moving parts, and has no gearing at all. As you can see in figure 4–7A, it consists of a spring-loaded piston connected to the pressure source so that the piston is moved outward against the spring's thrust by the fluid under pressure. Figure 4–7B shows how this movement is registered by a pointer on the face of the gage.

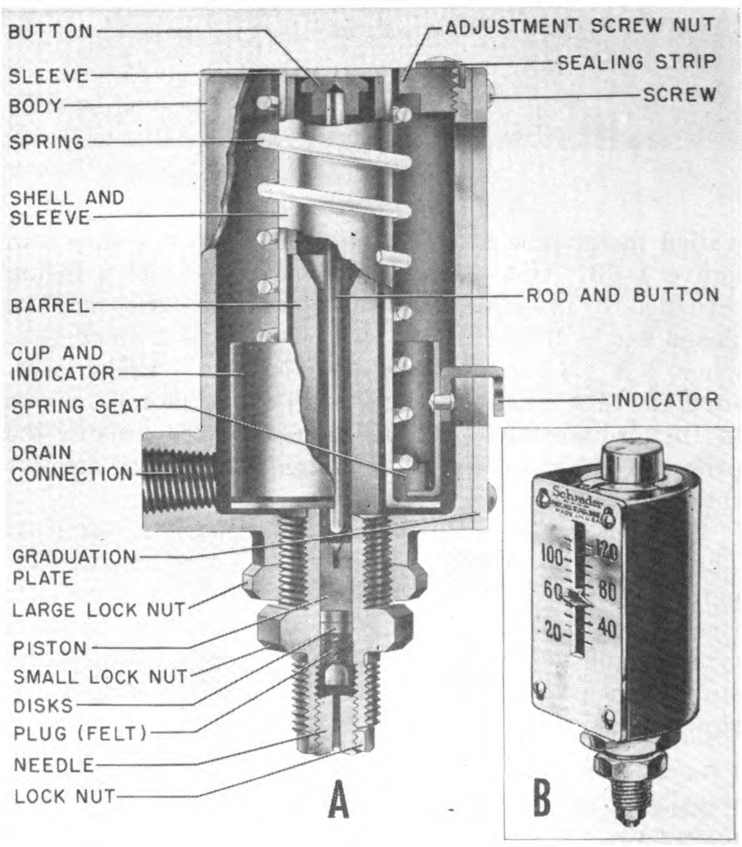


Figure 4–7.—Schrader gage.

Because you may have occasion to make minor adjustments on the Schrader gage (no adjustments at all on the Bourdon type are permitted by ordnance personnel), it's worth a slightly more detailed examination than we gave the Bourdon type.

The Schrader gage must be CALIBRATED when its readings become inaccurate—that is, it must be adjusted so that it reads true pressures. This is done by comparing gage readings with known pressures. A small error can be corrected by loosening the four screws on the face of the gage and sliding the scale up or down under the pointer. For larger errors, the adjustment screw which holds the spring in place can be tightened if the gage reading is too high, or loosened if too low. Turning the adjustment screw varies the compression of the spring. A sealing strip locks the adjustment screw in place after calibration.

The inner core of the gage can be removed for cleaning or for replacement of parts by loosening the small locknut at the base and the large locknut just above it, then unscrewing the barrel from the body. In removing parts, be sure to observe their relative positions as given in figure 4–7. In reassembly, rescrew the barrel into the body until the indicator marker moves 1/16 inch. Then tighten the large locknut. If the needle at the base is screwed into place too tightly, readings will be sluggish; if too loosely, readings will be jumpy.

The other interior parts can be reached by removing the face plate and unscrewing the adjustment screw nut, after breaking the solder seal of the sealing strip. Mark the exact position of the adjustment screw nut on the casting with a knife or chisel, so it can be properly positioned when the sealing strip is resoldered.

Care of Schrader gages is similar to that recommended for Bourdon gages. Protect them against vibration, excessive temperatures, corrosive liquids, and sudden high pressure. Install a petcock between the gage and the pressure system so pressure can be applied slowly, and to protect it against strain when not in actual use.

Precautions for Pressure Gages

Here are some general precautions to remember in connection with pressure gages of any type:

1. Don't use pressure gages on systems whose maximum pressure exceeds the maximum gage reading.
2. Don't be a butterfingers—dropping a gage may permanently damage it.
3. Check gages periodically for accuracy against a master gage.
4. When gages are not in use, stow them in a dry place.
5. Never use on an air line a gage that has been on an oil line. Oil will burn in compressed air; in fact, that's the principle of the Diesel engine. Don't try to demonstrate the principle with a pressure gage.

VALVES

As we noted earlier in this chapter, a valve is simply a device for directing and controlling the flow of hydraulic fluid or for regulating fluid pressure. Since every ordnance hydraulic system depends on the control and direction of its fluid, you can see that every hydraulic system must have valves in some form.

With respect to functioning, all valves can be classified as SIMPLE, COMPOUND, or DIRECTIONAL. A simple valve requires only a SINGLE INTERNAL MOTION for its operation. A compound valve involves a COMBINATION OF INTERNAL MOTIONS for its operation. Directional valves control the DIRECTION of fluid flow along two or more paths. In the next section we begin with simple valves.

Simple Valves

The idea of valves is one of the oldest in applied hydraulics. The Egytians used the idea in the sluice gates of their early irrigation systems. The idea must be good, because we use the same principle in our modern gate valves.

Petcock

The simplest kind of valve that you can expect to come across is the PETCOCK, or COCK (fig. 4–8). The cock has a plug permanently seated in the pipe. Through the plug runs an opening. When the cock is open, fluid flows through the opening in the plug. To shut off the flow, you simply give the plug a quarter turn, so that the solid side of the plug blocks the fluid.

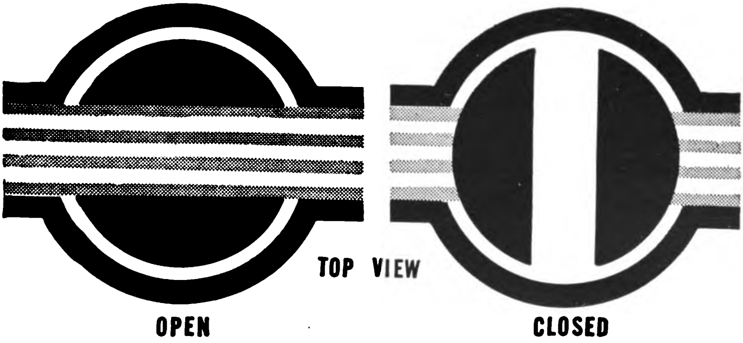


Figure 4–8.—Functioning of the petcock.

Small cocks are sometimes used to VENT hydraulic systems—free them from accumulated air. The cock is opened so that the air can escape. When liquid begins to flow continuously, the cock is closed. You'll also find petcocks used to check oil levels on supply tanks of hydraulic elevation and train power drives.

Gate Valves and Globe Valves

In GATE VALVES, flow is controlled by a wedge or gate that can be moved up and down across the line of flow by a handwheel (fig. 4–9). When the valve is open, the gate is up inside the BONNET. When it is closed, the gate blocks flow by standing straight across the pipe, where it rests firmly against two seats extending clear around the pipe.

Gate valves permit straight flow and offer little or no resistance to the liquid when the valve is completely open. Although you'll find that they may be left partly open to throttle flow, they are really intended for "all-or-nothing-at-all" use. If the valve is left partly open, its face may be eroded.

Gate valves are not easy to open or close if the pressure is high. For this reason, they are not very common in ordnance high-pressure systems; but you can find them installed as main valves in magazine flooding or sprinkler systems.

Gate valves are made with three types of stem connections. In one type, the stem does not rise or fall outside the body of the valve as the valve is opened or closed. There is no way of telling whether this type of valve is opened or closed, except by actually trying it. In the type illustrated in figure 4–9 the stem and handwheel rise

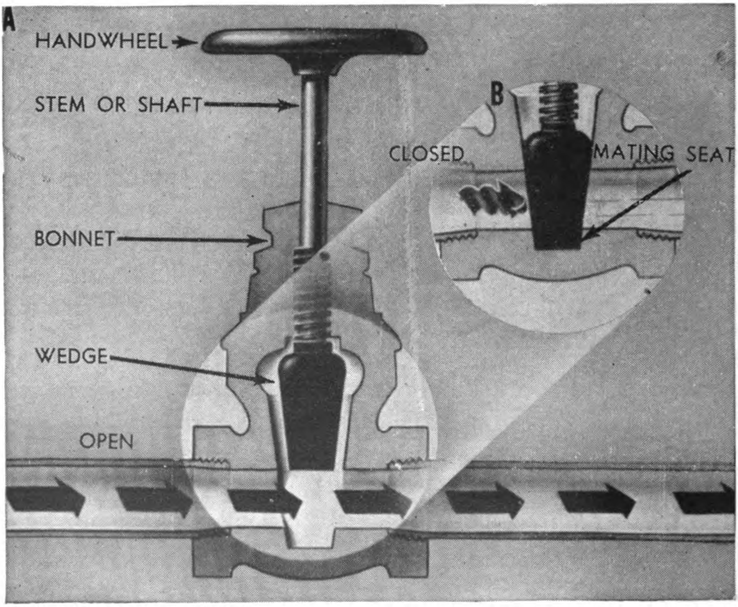


Figure 4–9.—Functioning of the gate valve.

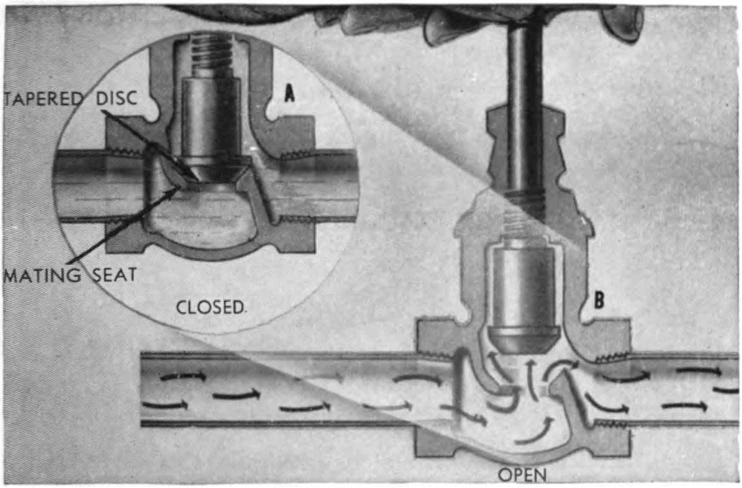


Figure 4–10.—Functioning of the globe valve.

when the valve opens. In the third type, the stem rises independently of the handwheel when the valve opens.

Valves with rising stems are used when it is important to know by immediate inspection whether a valve is open or closed; for example, in automatic sprinkler systems, where valves are ordinarily kept open. The nonrising stem type is less likely to leak, and needs less room.

WARNING:—Be careful not to force valves with nonrising stems.

In its general function and purpose, the GLOBE VALVE (fig. 4–10) is much like the gate valve. It's used for the same general type of work. In the globe valve, the controlling member, called the DISC, is screwed directly on the end of the stem. The valve is closed by lowering the disc onto the valve seat. Since the liquid flows equally on all sides of the center of support when the valve is open, there is no unbalanced pressure on the disc to cause uneven wear.

Although it is possible to adjust the rate of flow through a globe valve by partially closing it, the globe valve is not ideally adapted for such service. The best type for this purpose is the NEEDLE VALVE.

Needle Valves

Needle valves end in a tapered point which allows the valve to be opened or closed very gradually (fig. 4–11).

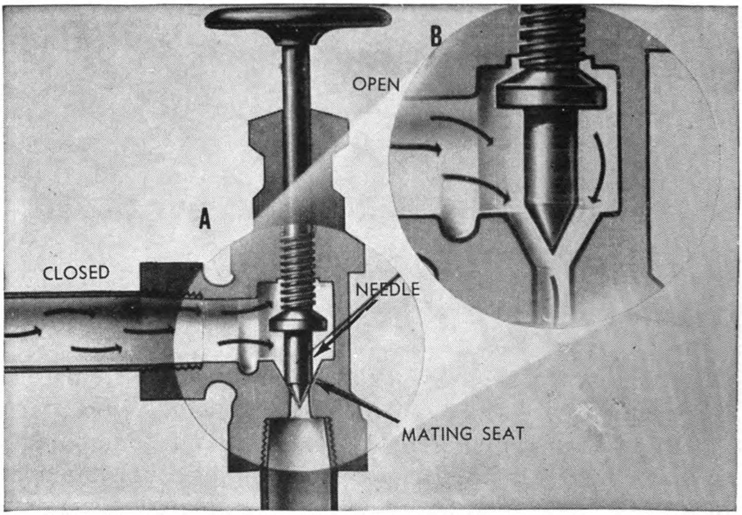


Figure 4–11.—Functioning of the needle valve.

Such valves are used to control the flow of liquid into delicate gages (pressure gages, for example) which might be injured if fluids under high pressure were suddenly delivered to them. This type of valve is also used to control the end operations of a work cycle, when work motion must be halted gradually, as, for example, in gun recoil systems. You can expect to find needle valves at points where the system requires precise adjustments of a small rate of flow.

Check Valves

Up to this point we have been considering hand-operated valves—valves that require the attention, to some degree, of a human operator in order to function at all.

But we find that the overwhelming majority of the valves in any ordnance hydraulic system are partly or completely AUTOMATIC and, of the automatic valves, the most frequent are CHECK VALVES of some type.

Check valves are not, and in fact cannot be, manually operated. That's why a check valve looks externally (when it's visible) like nothing more than a bump or a bulge on a pipe, with no handwheel, crank, or lever in sight.

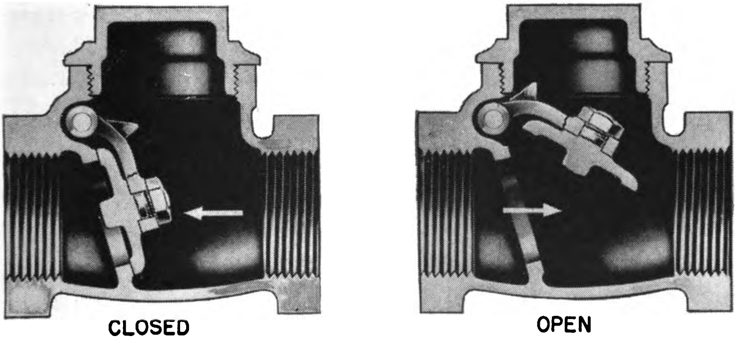


Figure 4–12.—Functioning of a typical check valve.

Check valves permit flow in but one direction, and close automatically when flow either reverses or ceases (fig. 4–12). Fluid pressure opens the check valve; it may be closed by gravity, by reversed fluid pressure, or by a spring.

Check valves are used in practically all ordnance hydraulic systems that use valves at all, in any form, though they are not always called check valves. However, you can easily recognize check valves by function, whatever the name.

Relief Valves

In most power-driven hydraulic systems it is important to limit maximum fluid pressure to a safe and efficient value. RELIEF VALVES are used for this purpose.

As you can see in figure 4–13, a simple relief valve is fundamentally nothing more than a check valve with a spring adjusted to compress when the fluid pressure reaches a certain value. The valve then opens, by-passing the fluid out of the system or back into a reservoir or tank.

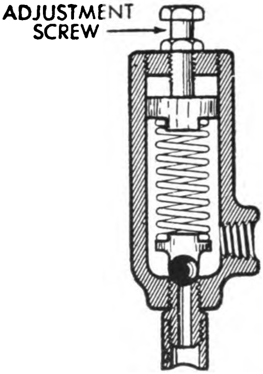


Figure 4–13.—Simple relief valve (cross section).

The valve is controlled by an adjustment screw seated against the top of the spring. An inward adjustment of this screw increases the compression of the spring, making it able to resist a higher pressure.

To protect as much of the hydraulic system as possible, relief valves are generally installed close to the source of pressure.

Pressure-Regulating and Pressure-Reducing Valves

The many different units within large hydraulic mechanisms, like power drives, require different pressures in order to function. One pump can, however, supply fluid at only one pressure. One way to furnish different pressures would be to have a separate pump for each, but it would obviously be wasteful. The usual practice in ordnance hydraulics, therefore, is to have one or at most two pumps supply hydraulic fluid at high pressure, and use

PRESSURE-REGULATING VALVES or PRESSURE-REDUCING VALVES to adjust these pressures to the desired values.

Note the distinction between pressure-regulating and pressure-reducing valves:

A PRESSURE-REGULATING valve is a kind of relief valve branching off the main line. It regulates pressure in the line to which it is connected simply by DUMPING (releasing or exhausting) excessive fluid when pressure goes too high. The only fluid passing through it is the fluid it dumps. This kind of valve has only two ports: input (or high-pressure) and exhaust.

A PRESSURE-REDUCING valve, on the other hand, is so placed in the line that ALL the fluid must flow through it. The valve admits to the reduced-pressure area only the fluid that will actually be used there. Excess fluid never gets into the reduced-pressure area; the valve bypasses it to the exhaust line. This kind of valve has three ports: input (high-pressure), reduced-pressure, and exhaust.

The simple spring-loaded relief valve can successfully be used as a pressure regulator (fig. 4–14). Whenever the pressure being supplied exceeds the level for which the valve is set, the pressure on the face of the piston pushes it back against the resistance of the adjustable valve spring. The piston thus uncovers an exhaust port. When pressure drops, the port is closed again. In the G. E. hydraulic drive for the single 5"/38 mount, a battery of

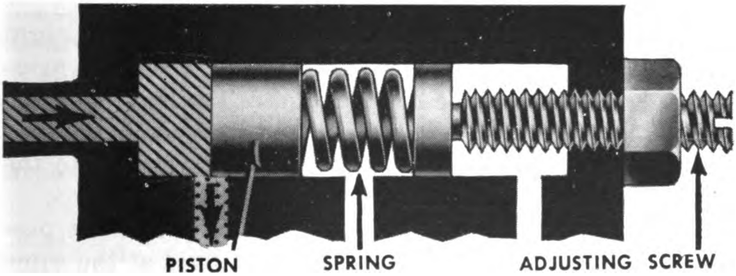


Figure 4–14.—Functioning of pressure-regulating valve.

five of these valves is connected in series, giving a selection of five different regulated pressures from 350 psi to 30 psi.

There are a great many other designs of this kind of valve, most of them more elaborate than this, but the basic functioning is the same.

Now let's consider a typical pressure-reducing valve. Figure 4–15 illustrates a type to be found in the Ford power drive for the 5"/38 twin mount. Here we have

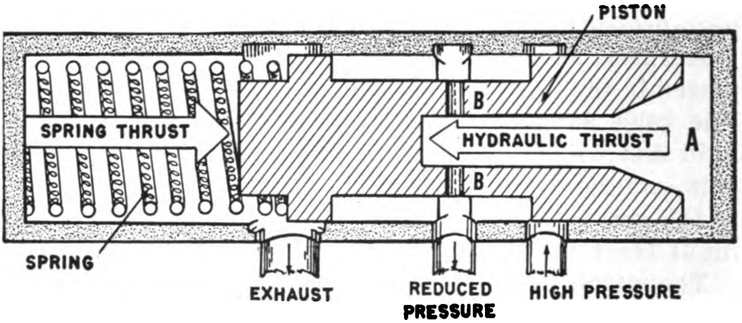


Figure 4–15.—Functioning of pressure-reducing valve.

a single spool-type piston that can move either to the right by the thrust of a spring, or to the left by hydraulic pressure. Movement to the right uncovers the high-pressure port. Movement to the left at first restricts and then cuts off input from the high-pressure port; movement to the left also opens the exhaust port.

To understand this valve's operation, notice that passage B and cavity A are always full of fluid at the same pressure as that in the line to the reduced-pressure area, and the fluid at the right end of the piston therefore causes a leftward thrust proportional to its pressure. Opposing this hydraulic thrust is the rightward thrust of the spring. When hydraulic pressure declines at the middle port, so does the leftward hydraulic thrust on the piston. The spring then pushes the piston to the right, allowing more high-pressure fluid from the pump to enter the valve. When pressure rises too high, hydraulic thrust pushes the piston to the left, closing the high-pressure inlet port and opening the exhaust port to the tank.

With pressure-reducing valves, as with regulating valves, you may encounter designs different from the one discussed here, but the example we have considered illustrates the functioning of this type of unit.

Compound Relief Valves

The valves we discussed up to this point have been simple units—simple in that they contain only one system of movable parts. And, as we have seen, these simple valves are a versatile lot—they can be made to do a great many things.

Simple valves, however, have their limitations. For instance, let's consider the simple relief valve, whose function is to keep pressure from rising above a certain level when the system is temporarily overloaded. In practice, the simple relief valve may not do this simple job as well as required. When it opens, if the volume of flow to be handled is greater than the capacity of the valve, pressure in the system may rise as much as several hundred psi above the set figure before the valve brings it under control.

Moreover, once the valve opens, it will not close until the pressure falls well below the pressure at which it is set. (Why? Because the open valve presents a greater area to fluid pressure than when seated.) Hence a simple relief valve is likely to open and close rapidly as it oscillates or HUNTS above and below the set pressure, causing pressure pulsations, undesirable vibrations, and noisy chatter.

To get around these drawbacks, we use COMPOUND RELIEF VALVES, in which two valve units operate together to do a specific job. The three compound relief valves you'll encounter in Navy ordnance hydraulic systems are:

1. The Vickers Hydrocone
2. The Northern Simplex
3. The Northern Duplex

You'll find the Vickers Hydrocone in many places—for instance, in the 6"/47 (*Cleveland* class) power rammer, in the Ford power drive for twin 5"/38 mounts, and in 5-inch powder hoists. You'll find the Northern valves (particularly the Duplex) in systems manufactured by Northern Ordnance.

The big advantages of compound relief valves are:

1. They can pass large volumes of hydraulic fluid—more than the pump can supply. When a compound valve is wide open, pressure in the system MUST drop.
2. They can operate within a narrow range of pressures. If a compound valve opens at 500 psi, for instance, it can close when pressure falls not far below 500 psi.

In all compound relief valves, a relatively small PILOT VALVE which can pass only a small amount of hydraulic fluid, controls a much larger MAIN VALVE.

Vickers Hydrocone Valve

In this course, we'll take up the Vickers Hydrocone, which is in basic operating principle quite similar to the Northern Simplex and Duplex, but is the easiest of the three to understand.

In figure 4–16A the main valve, which consists of a PISTON and STEM, is closed, blocking flow from the high-pressure line to the tank. Hydraulic fluid in the high-pressure line flows around the stem of the main valve on its way to the work. The stem of the main valve is hollow (this is the STEM PASSAGE), so that fluid can flow from the pilot valve, past the MAIN SPRING, which holds the main valve against its seat, down to the low-pressure or tank line.

The main valve piston also has a narrow PISTON PASSAGE through it, connecting the high-pressure line to the VALVE CHAMBER. From the top of the valve chamber another passage leads to the pilot valve.

The pilot valve is a small ball-type spring-loaded check

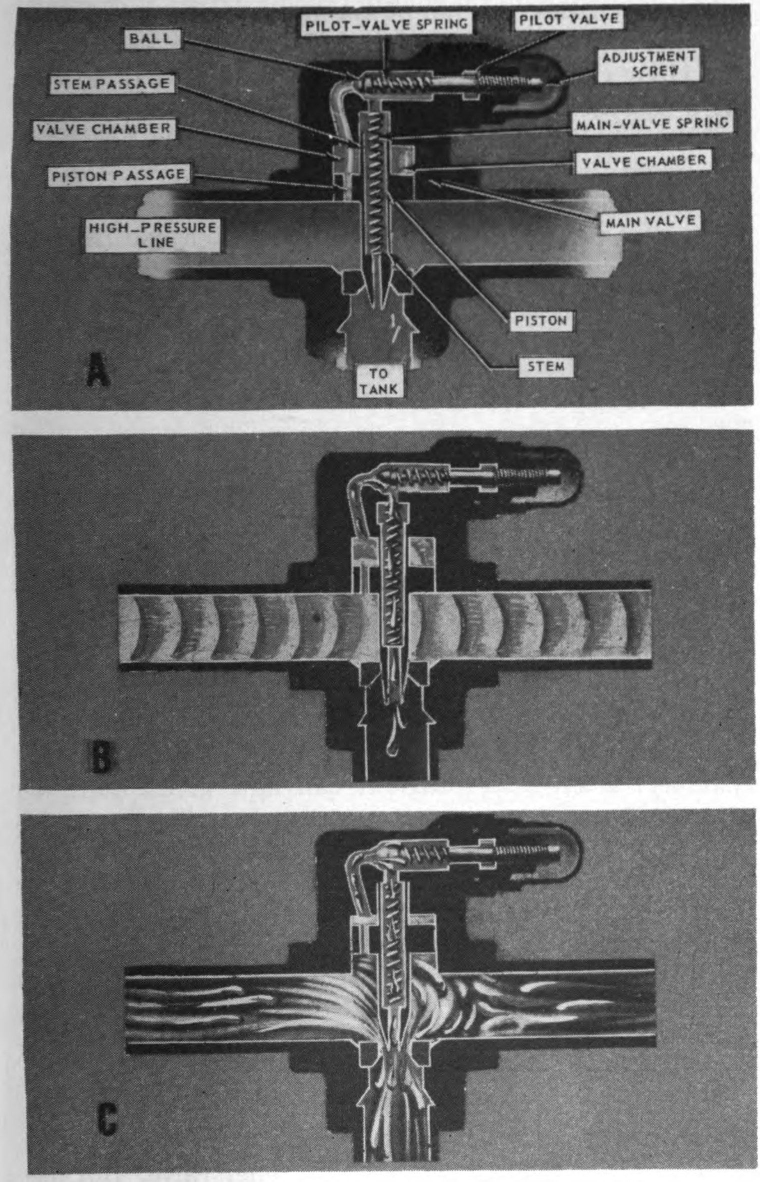


Figure 4–16.—Functioning of the Vickers Hydrocone.

valve, connecting the top of the passage from the valve chamber with the passage through the main valve stem. The PILOT valve spring's tension can be adjusted by turning a screw. The pressure at which the valve will operate depends on the tension of the spring.

Now let's set the valve into operation.

Hydraulic fluid at line pressure flows through the narrow piston passage to fill the chamber. Because line and chamber are connected, the pressure in both is equal. You will note that the top and bottom of the main piston are equal in area; hence the hydraulic forces pushing it upward and downward are equal, and there is no tendency for the piston to move hydraulically in either direction. The only other force acting on the main valve is that of the main valve spring, which holds it closed.

The pilot valve is the control unit. Its spring is so adjusted that the ball will unseat when pressure reaches the preset limit.

At normal pressures the ball remains seated. But now let the pressure in the main line rise to the point for which the pilot valve is set.

The ball is unseated (fig. 4–16B), opening the valve chamber through the valve stem passage to the low-pressure line. Fluid immediately begins to flow out of the chamber, much faster than it can flow in through the narrow piston passage. As a result the chamber pressure immediately drops, and the pilot valve begins to close again, restricting the outward flow of fluid. Chamber pressure thereupon goes up, the valve opens, and the cycle repeats.

The whole cycle takes place much faster than it takes to tell it—so fast, in fact, that the rapid back-and-forth movements of the valve become high-frequency vibration, and the valve hums or sings as the pressure goes up.

So far, the only part of the valve that has moved appreciably has been the pilot, which has functioned just like any other simple spring-loaded relief valve. But, because of the narrowness of the piston passage, there's a severe limit on the amount of flow through the pilot valve, and therefore on the amount of relief it can give the system. All the pilot valve can do is limit hydraulic pressure in the valve chamber above the main piston to a preset maximum value. In doing this, the pilot also limits main-line pressure, by drawing off excess fluid through the piston passage. But when the main-line pressure rises to

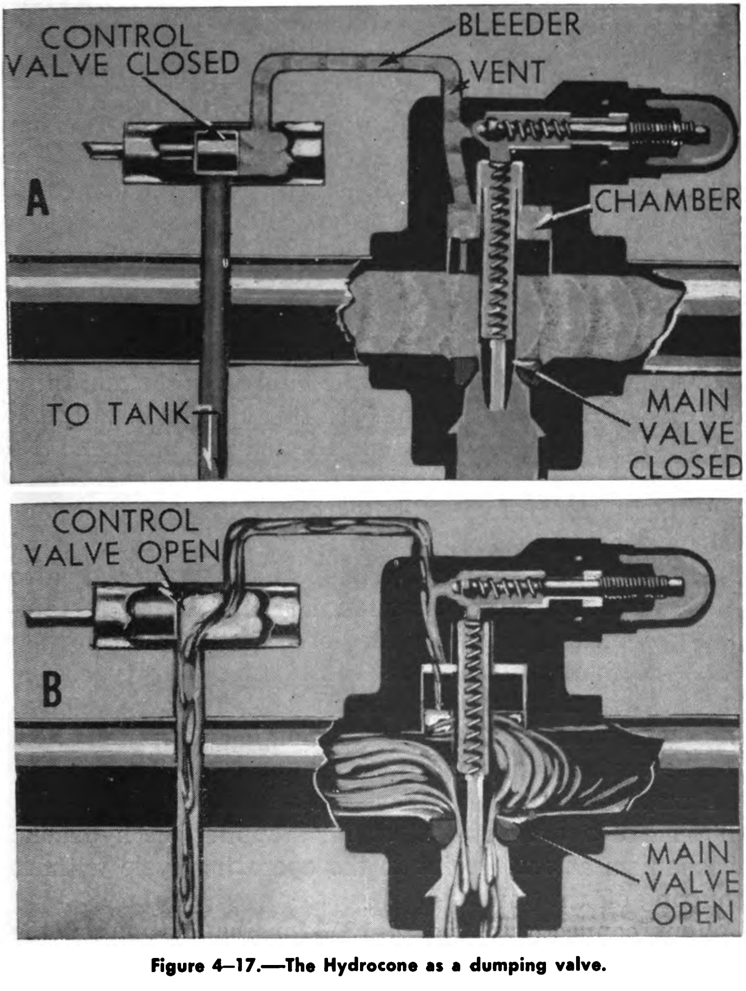


Figure 4–17.—The Hydrocone as a dumping valve.

a value where flow through the pilot cannot draw off enough fluid to have sufficient effect, the main valve, up to now inactive, plays its part.

As main-line pressure goes higher, the increasing upward force on the main piston can equal and at length overcome the limited downward force, which consists of the spring's thrust plus the hydraulic thrust of the fluid in the valve chamber (fig. 4–16C). The piston then rises, unseating the stem, and vents the main line directly to tank or reservoir.

Main-line pressure drops rapidly, since the main valve can pass more fluid than the pump can supply. When pressure returns to normal (which it soon does), the pilot spring reseats the ball. Again pressures are equal above and below the main piston, and the spring in the main valve stem returns the main valve to its seat.

In some equipment, the Hydrocone acts not only as a relief valve, but also as a DUMPING or UNLOADING VALVE, which can be controlled to reduce system pressure at will by venting or dumping hydraulic fluid from the main line directly to reservoir or tank. In this kind of installation (fig. 4–17), a control valve is connected by a BLEEDER LINE to a vent leading to the main valve chamber.

With the control valve closed, the Hydrocone functions solely as a relief valve, in the way we've described. However, when the control valve is opened, venting the valve chamber to the tank, pressure in the chamber drops. Main-line pressure, overcoming the force of the main spring, lifts the main valve off its seat. In some Hydrocone valves, the fluid can be dumped in this way only to 60 psi; in others, where main-spring tension is lower, the system can be vented pretty nearly to zero pressure.

Dumping or unloading a system is useful for cushioning the end of a work stroke, or for stopping the hydraulic mechanism at some point in the operating cycle without shutting off the power.

Vent connections (fig. 4–18) for installation of the bleeder line are located in the top of the Hydrocone case.

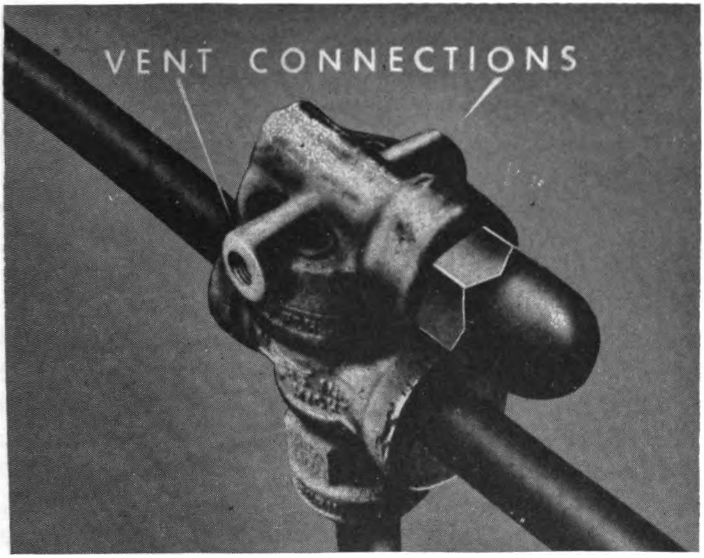


Figure 4–18.—Vickers Hydrocone exterior, showing vent connections.

When not used, the vents are closed by plugs. Either vent may be used if the Hydrocone is level; if it's tilted, the bleeder should be connected to the HIGHER vent.

Directional Valves

Up to this point we have seen how valves regulate fluid pressure and control the volume and velocity of fluid flow. However, valves can also DIRECT the flow of liquids in hydraulic systems. Suppose, for example, that a hydraulic system performs a work operation by driving a piston back and forth in its cylinder. A directional valve, which would function alternately to admit and then drain off liquid from each end of the cylinder, would make this possible.

Some directional valves are positioned hydraulically by difference of force set up on opposite sides of their movable parts. Other types of directional valves may be positioned by hand, by mechanical means, or by electric power.

Directional valves can be classified by the number of hydraulic openings or PORTS they have. A FOUR-WAY (four-port) VALVE (fig. 4–19) would be the minimum necessary to operate a work cylinder of the kind mentioned in the preceding paragraph. Such a valve would have one connection to the source of pressure (probably a pump), a second to the reservoir of the system, a third to one side of the work cylinder, and a fourth to the other side.

The commonest type of directional valve is the SPOOL VALVE. Figure 4–19 shows a four-way valve of this type. The two pistons of the valve can slide back and forth, blocking and uncovering the ports, depending on their position. It's obvious from the shape of the pistons why this type is called a "spool" valve. Note these features, common to many spool valves:

1. The drain openings at either end of the cylinder prevent back pressure from building up in the cylinder and hindering movement of the piston.
2. When spool valves become worn they tend to lose balance, because one piston usually leaks more than the other. The spool then tends to stick. Small grooves are therefore machined around the sliding surfaces of the spools. When the spools begin to wear, liquid leaking through the grooves keeps them lubricated and centered.

The valve pictured in figure 4–19 has three positions. In part A, you see it in NEUTRAL (central position). The fluid from the pump can enter through the middle port at the top of the valve but the piston blocks ports L and R, and the valve delivers no fluid to the work area.

When the valve is thrown to the LEFT (fig. 4–19B), port L gets the flow of high-pressure fluid, and R opens to the reservoir (port at the bottom of the valve).

When the valve is thrown to the RIGHT its action is reversed (fig. 4–19C). Port R opens to fluid from the pump, and port L opens to the reservoir.

Now let's put our four-way spool valve to work (fig. 4–

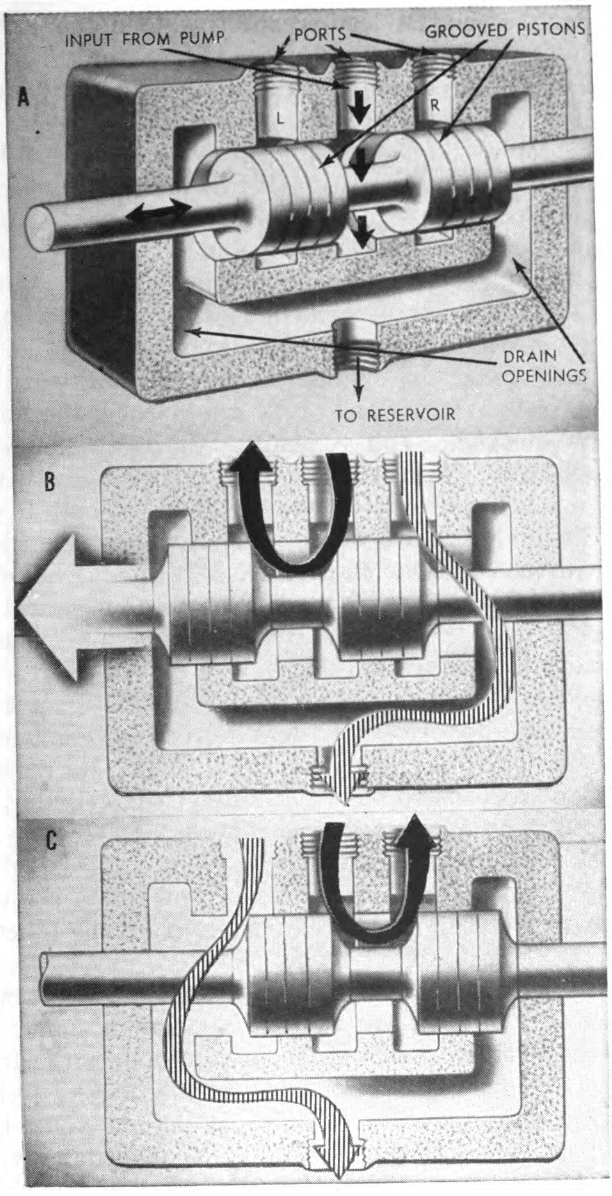


Figure 4–19.—Four-way spool valve.

20). Ports L and R lead, respectively, to the left and right sides of the work cylinder. When the valve is in NEUTRAL position, no hydraulic liquid flows through to the work cylinder, because ports L and R are both blocked. When the hydraulic system is full of liquid (which is its normal condition), this means not only that no liquid is delivered to the work cylinder, but also that the work piston is LOCKED IN PLACE.

This should be obvious. If it is not, look at figure 4–20A. Note that the work cylinder is connected only to ports L and R. If the work piston moves to the left, liquid must enter the cylinder through R and leave (exhaust) through L. If the ports are blocked, the flow of liquid is blocked. You remember that liquids are INCOMPRESSIBLE. An outside force acting on the work piston must, in order to move it, be great enough to compress the liquid in the system. Any such force exerted on a system like the one illustrated here would burst the hydraulic lines and mechanisms. So, for all practical purposes, the work cylinder is locked in position when the spool valve is in NEUTRAL.

When we throw the valve to the LEFT (fig. 4–20B), high-pressure liquid through port L to the left side of the work cylinder drives the piston to the right. At the same time, port R opens to the right side of the cylinder, and the liquid there exhausts to the reservoir (which we here consider to be at zero pressure).

Figure 4–20C shows the paths of flow when the valve is thrown to the right; you can easily trace the functioning of the system for yourself.

In emergencies (for instance, a power failure), it might be necessary to operate a system like this by hand. Because the system is locked when liquid is not actually pumped through it, there should be some way of unlocking it for hand operation. A simple method would be to connect both ends of the work cylinder externally with a BYPASS LINE. Then the liquid could flow from one side of the cylinder to the other as the piston moves back and

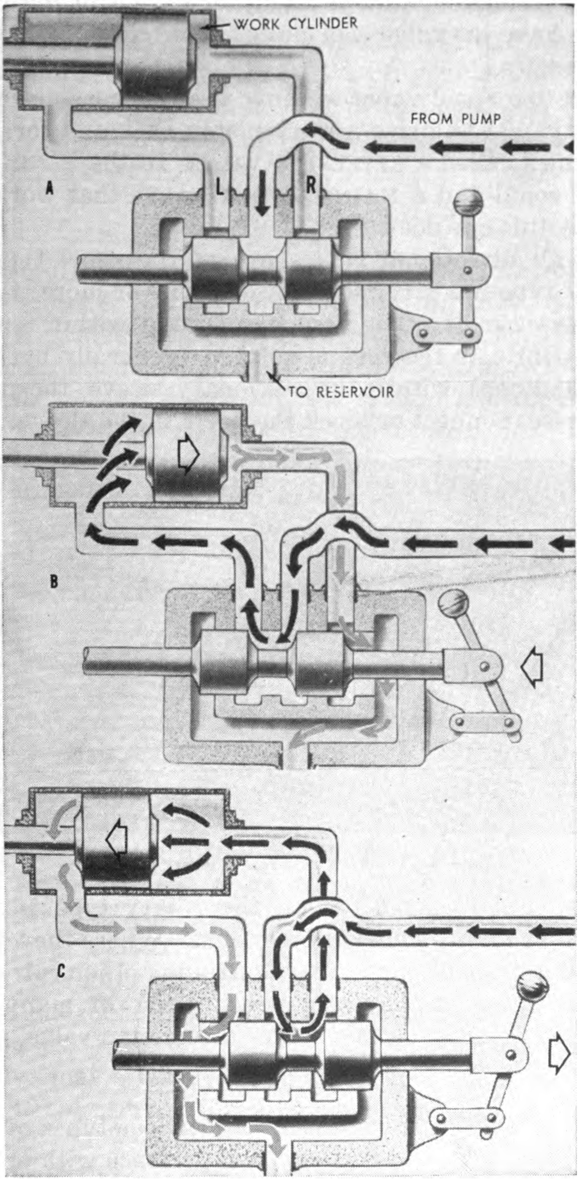


Figure 4–20.—The spool valve at work.

forth. Naturally, such a line (not shown in the figure) would have a valve normally kept closed, except in emergencies.

Since the spool valve we have been discussing is often used this way to drive a work piston back and forth, it is sometimes called a REVERSING VALVE. In the 5''/38 single mount you'll find a MAIN CONTROL VALVE that works just the way this one does.

Not all directional valves are of the spool type. The ROTARY type has a round CORE with one or more passages or recesses in it. The core is mounted within a SLEEVE (fig. 4–21). As the core is rotated (generally by a hand lever or knob) within the stationary sleeve, the passage or recesses connect or block the ports in the sleeve.

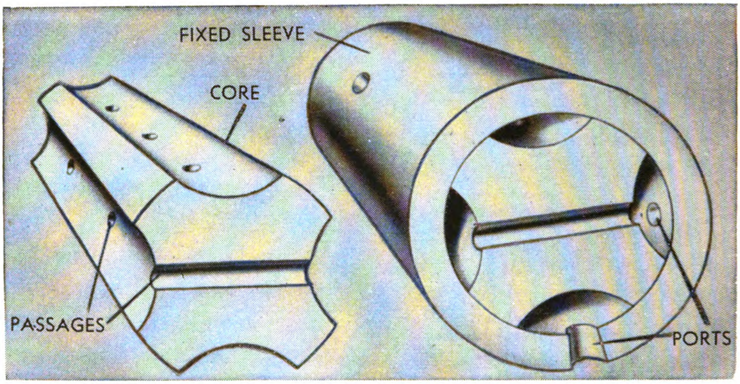


Figure 4–21.—Parts of a rotary directional valve.

Compared to spool valves, the rotary type is seldom used on ordnance hydraulic systems. Where they do turn up, you'll probably find them controlling other valves. The selector valve in the train power drive of many 5''/38 mounts, for instance, is a rotary directional valve.

VALVE MAINTENANCE

In this chapter we've discussed various types of valves individually. However, in your experience with ordnance hydraulics, you'll deal with valves not individually but as parts of functioning systems. You shouldn't, therefore, get the idea that this section is the last word on valve maintenance. It isn't. The OP's on your equipment are intended to give you that kind of information. In this section you'll find tips that will be generally useful to you in your work with valves.

Hand-Operated Valves

To begin with, you should open and close hand-operated valves SLOWLY. Do not force any moving part against its seat. If a valve refuses to seat properly, open it slightly so that sediment on the seat will be flushed away. If it still fails to seat, shut down the system and disassemble the valve to locate and correct the trouble.

Inspect all valves regularly. Do not turn a valve stem with a wrench. Do not remove the turning wheels from valves. Hand-operated valves of all kinds should be tested at least four times a year.

Valves in Hydraulic Systems

The successful operation of a hydraulic system depends upon the proper operation of the valves in that system. The operator should know what valves must be open, and what valves closed. If the system has been operated previously, the automatic valves, such as regulators, relief valves, safety valves, etc., should not be disturbed until found faulty or until time for periodic checkup. Always check up on the open or closed position of all hand-operated valves before it is time to start the system.

Improper action of a hydraulic system can often be traced to faulty valve action. This is usually due to foreign matter in the valve seat, to scoring or grooving of meeting parts, or to plugging of openings. As a result the valve may stick, or may fail to close completely.

The usual remedy for such conditions—as, in fact, for practically all serious valve troubles—is to dismantle the valve, thoroughly clean all parts, replace those that are damaged, and reassemble. At first you will do this only under the supervision of your chief, but you will gain expertness with practice.

Maintenance of compound relief valves is fundamentally the same as that of simpler types. You can generally tell that a compound relief valve is not functioning properly because it will overheat, and will operate sluggishly, erratically, or at the wrong pressure. The most frequent cause of trouble is the presence of foreign matter in openings or on seats. The valve will usually clean itself if you start the pump and back off the adjustment screw on the pilot valve a little by turning it counterclockwise, so that the pressure control spring responds to a lower pressure. (The adjustment screw should never be completely removed with the system under pressure.) After the flow of liquid has cleaned the valve, carefully reset the adjustment screw, using a pressure gage. The relief valve should be set to open at about 25 percent above the maximum normal operating pressure.

OTHER HYDRAULIC COMPONENTS

The hydraulic gear with which we have been chiefly concerned in this chapter is intended for conveying, directing, and controlling the flow and pressure of hydraulic fluid. It is time now for us to take up the way in which hydraulic flow and pressure are produced and how they are utilized in ordnance hydraulic systems to do useful work—ram projectiles, train and elevate guns, hoist ammunition, and perform a number of other tasks around the modern naval gun mount. In the next chapter, therefore, we'll take up more complex types of hydraulic mechanisms—pumps and motors.

QUIZ

In the following, select the one BEST answer for each question

1. Pressure head of a liquid varies with
   a. shape of the container
   b. diameter of the piston
   c. magnitude of the thrust
   d. height of the liquid column
2. Which of the following properties of a liquid can affect the pressure head that a column of it will develop?
   a. Density
   b. Viscosity
   c. Vapor pressure
   d. None of the above
3. Assume a closed cylinder, full of liquid, and a movable piston pushing down in it with uniform thrust. If we reduce the area of the piston, the pressure in the liquid in the cylinder will
   a. increase
   b. decrease
   c. remain the same
   d. No answer possible from the above information
4. As liquid flows through a narrowing pipe,
   a. its viscosity increases
   b. its velocity of flow increases
   c. its inertia decreases
   d. turbulence decreases
5. Fluid friction in a hydraulic system causes an increase in:
   a. heat
   b. viscosity
   c. velocity of flow
   d. fluid inertia
6. Which of the following types of valve is BEST adapted to throttle fluid flow by being partly open?
   a. Gate   c. Needle
   b. Globe   d. Check
7. The function of the pressure-reducing valve described in this chapter is to
   a. dump excess fluid when the system pressure gets too high
   b. reduce fluid input to the system when its pressure gets too high
   c. exhaust fluid to the tank to maintain tank pressure at proper value
   d. reduce pump output pressure in accordance with reduced output volume

8. When the pilot valve of the Hydrocone is closed, pressure in the valve chamber is
   a. equal to that in the main line
   b. equal to that required to balance main-spring thrust
   c. greater than that in the main line
   d. less than that in the main line
9. In figure 4–19A, in which the spool valve is shown in neutral (central) position, pump output is
   a. completely blocked
   b. dumped directly to the reservoir
   c. leaking around the grooves to the drain openings
   d. cut off at the pump
10. If a compound relief valve is giving trouble that seems to be caused by a particle of foreign matter on the valve seat, the FIRST thing to do is to
   a. start the pump and back off the pressure adjustment screw
   b. shut the system down, remove the valve, and replace it
   c. remove the pressure adjusting screw
   d. bleed off the hydraulic fluid

CHAPTER 5

HYDRAULIC MECHANISMS

INTRODUCTION

In the previous chapter we studied the characteristics of liquids, and the mechanisms (valves) that are used to control their pressure and flow. Now let's take up the hydraulic mechanisms and components that are used in doing work—namely, pumps, motors, and work cylinders—and the auxiliary units that are used for collecting and storing hydraulic fluid—namely, accumulators, tanks, air chambers, reservoirs, and sumps.

THE HEART OF THE SYSTEM

Let's begin with pumps.

First of all, what is a pump?

Most hydraulic systems require pumps. Even your own circulatory system, with its arteries, veins, and capillaries, has a pump—your heart. In any hydraulic system that has a pump, the pump is truly the heart of the system. It's the pump that circulates fluid through the hydraulic system of which it is a part, and it does this by pushing—by exerting force on the fluid. This is not to imply that a pump necessarily develops power of its own. Your heart is an unusual kind of pump in this respect, because it contains within its own structure the muscles that power it. Most other pumps require an outside source of power—an electric motor, internal-combustion engine, or a steam engine, for example.

We can answer the question by defining a pump as follows:

A PUMP IS A MECHANISM THROUGH WHICH AN OUTSIDE SOURCE OF POWER IS USED TO APPLY A FORCE TO A FLUID.

Though there are a number of types of pumps that we must consider in connection with ordnance hydraulics, they all include the following component parts:

A PUMP CHAMBER, in which the actual pumping action takes place.

An INTAKE PIPE or PORT, or SUCTION PIPE, or INLET, through which hydraulic fluid passes from the reservoir or supply tank to enter the pump.

An OUTLET, or DISCHARGE PIPE, or PORT to deliver the liquid pumped.

A SOURCE OF ENERGY, which in ordnance hydraulics is nearly always some type of electric motor.

Many pumps also have valves that are essential to their functioning. However, most of the pumps you will encounter in ordnance hydraulics are valveless.

FUNCTIONS OF HYDRAULIC PUMPS AND MOTORS

Not all hydraulic systems have pumps, but some systems have several, each serving a different purpose. One pump is the MAIN PUMP, and its function is to force the hydraulic fluid through the system to operate the mechanism (the gun mount, ammunition hoist, rammer, breech mechanism, or whatever) it is designed to operate. But what about the other pumps?

The REPLENISHING PUMP takes hydraulic fluid from the system's reservoir and forces it into the high-pressure lines, to maintain their full pressure and to make up losses from leakage.

The SUMP PUMP picks up oil from the sump and pumps it into the reservoir. In all hydraulic systems, even those in the best of condition and adjustment, there may be slight leakages. In a large and complex mechanism like a train or elevation power drive, there are so many hydraulic units, each of which may leak a little, that the total leakage adds up to a respectable amount. The leakage oil drains eventually into the SUMP at the bottom of the case of the system, whence the sump pump picks it up.

The COOLING PUMP circulates coolant through a jacket around a gun barrel to reduce its temperature.

Then there are HYDRAULIC MOTORS, which are really hydraulic pumps in reverse. Driven by hydraulic fluid under pressure, hydraulic motors operate gun mounts, ammunition hoists, and rammers of a number of types of turret guns.

Types of Pump Mechanisms

In ordnance hydraulics there are four generally recognized types of pump mechanisms:

1. Rotary
2. Centrifugal
3. Reciprocating
4. Axial-piston

ROTARY pumps have operating parts that revolve to exert force on fluids. They are the types you'll meet most often in ordnance hydraulics. Figure 5–2 shows a simple GEAR-TYPE rotary pump, which you'll recognize when you see it on 5"/38 rammers. Other rotary pumps you'll encounter may have vanes or lobes instead of gear teeth, may have one or two rotors, and may vary in other ways.

By and large, rotary pumps are valveless; the shape and relative motion of the moving and stationary parts of the pump provide whatever valve action is needed.

CENTRIFUGAL pumps also use the rotation of moving parts to exert force on liquids. The rotating parts, however, not only carry the fluid to the pump chamber, but utilize CENTRIFUGAL FORCE produced by their rotation to impart pressure to it. (See fig. 5–1.) Centrifugal pumps are not widely used in ordnance equipment, but the pump that circulates water through the cooling systems of twin and quad 40-mm mounts is of this type.

RECIPROCATING pumps depend for their functioning on the back-and-forth movement of their mechanical operating parts. Two types are shown in figure 5–15. Historically, reciprocating pumps are the earliest type of pump. They're not very common in ordnance hydraulics, but you'll find them in some systems as hand-operated emergency pumps, and in auxiliary units for charging high-pressure counterrecoil systems.

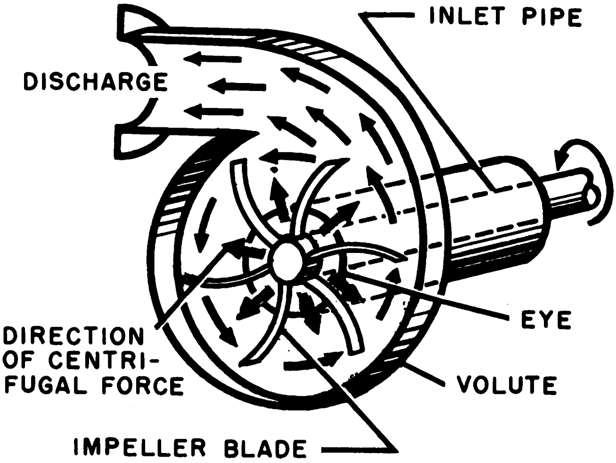


Figure 5–1.—Elements of centrifugal pump.

The AXIAL-PISTON pump ingeniously combines the principles of the rotary pump with the reciprocating type.

There are two other main types of pump—the JET or DIRECT-ACTING, and the PROPELLER. Both are used on board ship, but not in connection with ordnance hydraulics. You are therefore not expected to know them in connection with your job as a Gunner's Mate.

Characteristics of Pump Delivery and Displacement

Pumps can be classified also according to whether they discharge liquid in fixed amounts separated by periods of no discharge—POSITIVE-DISPLACEMENT—or in a continuous flow—NONPOSITIVE-DISPLACEMENT. Pumps also can be classified as VARIABLE-DELIVERY or CONSTANT-DELIVERY, according to whether or not the quantity of liquid discharged by the pump can be varied without changing the speed of rotation of the source of power.

In ordnance hydraulics you'll deal almost wholly with positive-displacement pumps of both constant and variable delivery type.

In positive-displacement pumps a definite volume of liquid is delivered for each cycle of pump operation, regardless of the resistance offered, provided resistance does not exceed the capacity of the power unit driving the pump. But in nonpositive-displacement pumps the volume of liquid delivered for each cycle depends on resistance offered to flow. If the outlet of a positive-displacement pump is completely closed, either the unit driving the pump will be stalled or something will slip or break. If the same thing is done to a nonpositive-displacement pump, the discharge pressure will rise to a maximum for that pump operated at that speed. But nothing more will happen, except that the pump will churn the liquid and produce heat.

Positive-displacement pumps deliver fluid in separate volumes, with no delivery in between, although a pump having many chambers may have an overlapping delivery that minimizes this effect. Nonpositive-displacement pumps deliver a practically continuous even flow for any given set of conditions of speed and resistance.

In general, we can say that the reciprocating, axial-piston, and rotary pumps are positive-displacement pumps, whereas jet, centrifugal, and propeller pumps are nonpositive-displacement pumps.

In naval ordnance hydraulic systems, all pumps are designed to operate at constant speed. In many cases, however, the system may require the output of the pumps to vary. Under these circumstances, a pump must be capable of changing its output volume (that is, the number of gallons per minute delivered) without varying in speed.

As far as nonpositive-displacement pumps (like the centrifugal type, for instance) are concerned, this problem is not important. For one thing, the HEAD or pressure against which such a pump is operating is almost as important as its speed in determining output; for another, pumps of this type are never used in ordnance hydraulic systems where the exact amount of output is a critical factor in the system's performance.

With positive-displacement pumps, however, this can be an important problem. In hydraulic power drives, for example, the gun's direction and speed of train (or elevation) depend completely on the direction, pressure, and volume of output of a positive-displacement pump running at constant speed in one direction.

The only way to vary output, under these conditions, is to alter the relationships and the movements of the mechanical parts of the pump itself while it continues to function. Positive-displacement pumps designed to permit this kind of adjustment are called VARIABLE-DELIVERY pumps. Positive-displacement pumps that do not permit such adjustment of output are called CONSTANT-DELIVERY pumps. A constant-delivery pump operating at unchanging speed will always deliver unchanging output. A variable-delivery pump operating at unchanging speed can be made to vary or even reverse its output, by making internal adjustments of its parts.

Now we'll study the principles of operation of the types of pumps that you'll be most likely to deal with in servicing, maintaining, and using ordnance equipment.

The two main classifications of pumps whose operating parts revolve are the CENTRIFUGAL and the ROTARY. Of the two, the rotary type is far the more important to you; but, because you will encounter one frequent application of the centrifugal type, let's consider its operating principles.

CENTRIFUGAL PUMPS

CENTRIFUGAL FORCE has an elegant five-dollar Latin name, but its explanation is not nearly so complicated as its pronunciation.

A couple of hundred years ago Sir Isaac Newton, the famous British mathematician, who according to legend was conked on the head by an apple and so was led to develop the law of gravity, formulated three Laws of Motion to explain the behavior of matter. The second of these three laws states:

"A body at rest tends to remain at rest, and a body in motion tends to continue in motion with the same velocity and in the same direction." Or, in other words, once you set something in motion, it tends to keep going straight along at the same speed.

Now suppose we try a little experiment. Take a shallow basin, and fill it about half full of water. With your hand whirl the water around. You'll notice that the water banks up around the sides of the basin, leaving the center low, or even waterless. And, if you whirl the water hard enough, it will splash over the side.

According to the Newtonian Law that we've just stated, the water tends to move in a straight line when it's pushed. However, the sides of the basin hold it in, forcing it to follow in a circular path. Because the water tends to go straight, it exerts force outward, so that if you push it hard enough it will mount the sides of the basin and spill over. This outward-tending force is what we call CENTRIFUGAL (Latin for CENTER-FLEEING) force. The greater the rate of rotation, the greater this force becomes.

In a centrifugal pump, you have instead of your hand, a set of paddles or blades (the IMPELLER), which whirls the water around (fig. 5–1). For reasons of design, which we won't go into here, the impeller blades are curved. Instead of the basin, you have a completely enclosed casing of special shape, the VOLUTE. The pump's outlet is at the outside edge of the casing. The inlet is through the center, or EYE.

When the pump operates, liquid enters the pump through the eye and is whirled around in the pump chamber by the rotation of the impeller. Centrifugal force drives the liquid directly outward from the center, setting up a greater pressure at the outer edge of the chamber than at the eye. At the same time the liquid is also pushed around and around in the pump by the turning of the blades, and is given more and more velocity as it moves farther out from the eye. As the liquid finally escapes into the discharge, it slows down, and, in effect, its velocity is converted into liquid pressure or head.

Incidentally, centrifugal pumps are used in ordnance hydraulics only for pumping coolants—water or water-ethylene glycol mixtures—never for pumping hydraulic oil. You will not find them in power drives or similar hydraulic gear. As previously stated, they are at present used for circulating coolants in 40-mm twin and quad mounts.

ROTARY PUMPS

Rotary pumps haven't quite as antique a history as reciprocating pumps, but they're nothing new. They didn't come into general use, however, until the electric motor became common. Electric motors are ideally adapted to drive rotary pumps, since it's necessary only to couple two rotating shafts. All the power-operated pumps you'll encounter in ordnance hydraulic mechanisms are driven through gear trains by electric motors.

Rotary pumps come in all sorts of shapes and sizes, and with all sorts of designs. The ones you'll study in this course are those commonly used in ordnance hydraulic systems, and they include:

Northern Nitralloy series 4000 gear pump
Vickers balanced-gear pump
Gerotor internal-gear pump
Northern internal-gear pump
Vickers balanced-vane pump

Axial-piston pumps, which combine the principles of both rotary and reciprocating pumps, are taken up later in this chapter.

The rotary pumps you will study may have either one

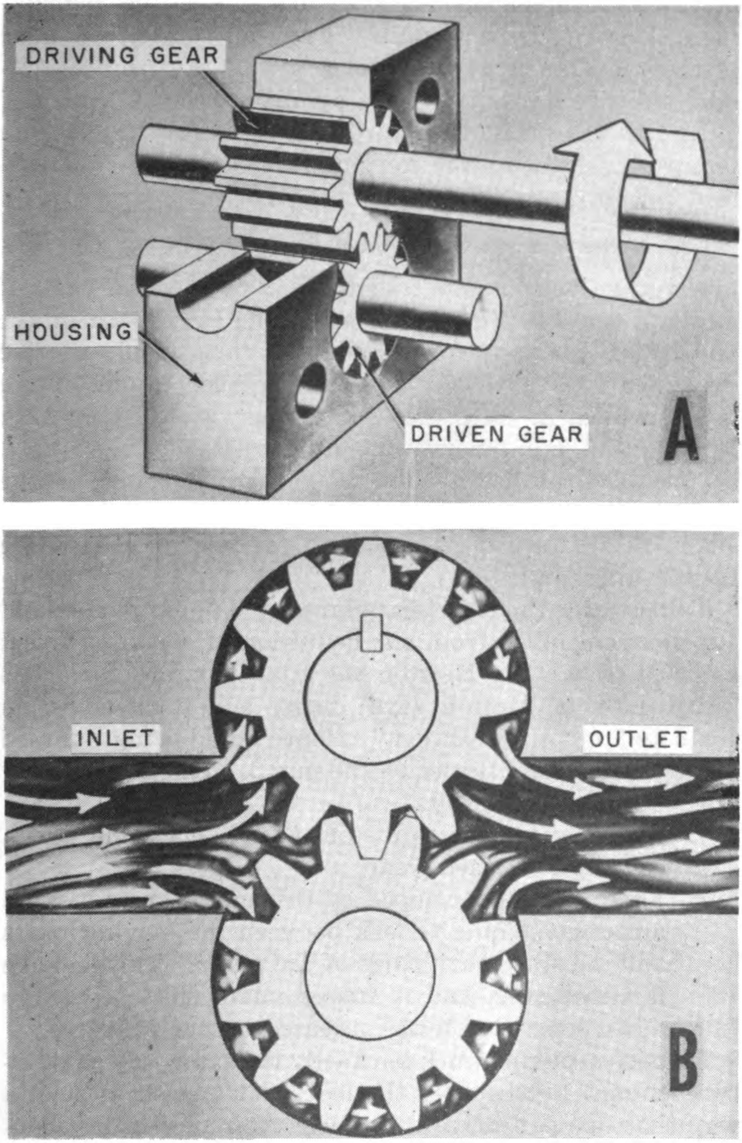


Figure 5–2.—Elementary gear pump. A. Construction. B. Functioning.

or two rotating elements. They are all positive-displacement constant-delivery units. They all rotate, but none of them use the centrifugal-force principle of the centrifugal pump to impart pressure to the fluid they pump.

Before we study the Northern Nitralloy or Vickers pumps, let's take up the elements of gear pump construction and functioning.

Elements of Gear Pumps and Lobe Pumps

A rotary gear pump essentially consists of a pair of meshing gears in a close-fitting housing fitted with intake and outlet openings for coupling to tube or pipe. The drive shaft of the power source is coupled to one of the gears, which, in turn, drives the other. (See fig. 5–2A.) In operation, liquid passes from the inlet side (fig. 5–2B), around between the gear teeth and the housing, to the outlet side. Because of the close contact between the two gears, no liquid can leak back to the inlet side between the meshing teeth.

To move the liquid being pumped, the pump parts must (as you remember from our definition of a pump) exert a thrust on it. But Newton has a law for this, too. His Third Law of Motion says: "Any action develops an equal and opposite reaction." Hence liquid being pumped exerts an opposite thrust on the pump. This back thrust (fig. 5–3) has two results:

1. The thrust tends to distort and displace the gears, causing increased wear.
2. The pressure developed by the pump forces a small amount of liquid to leak between the moving parts and the stationary parts of the pump. This leakage is called SLIP, and it causes pump efficiency to go down somewhat with increased output pressure.

LOBE-type pumps work in exactly the same way as gear-type pumps, but because the lobes don't mesh in such a way that one can drive the other, their mechanical connection must be made through external TIMING GEARS. Lobe-type pumps are not capable of dealing with the high

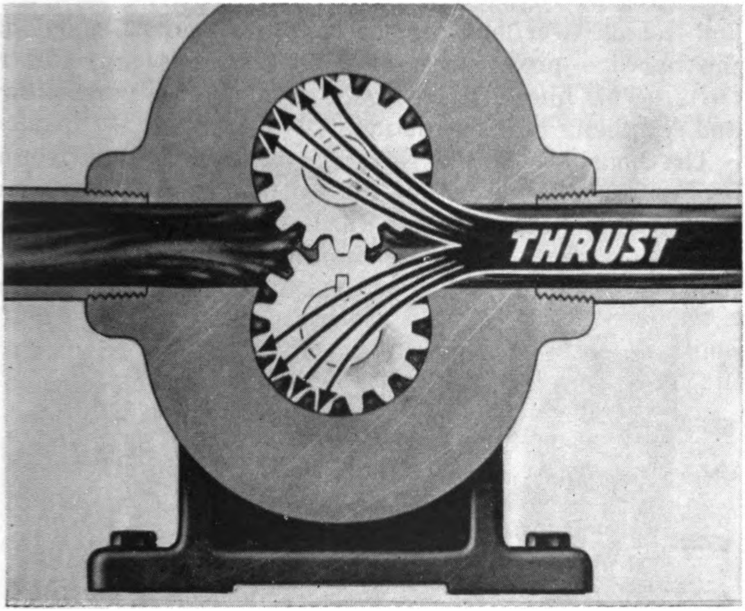


Figure 5–3.—Effect of back thrust in a gear pump.

pressures frequently used in ordnance hydraulic systems, and you will therefore come across them relatively rarely.

In the two commonest types of gear pump used in Navy ordnance equipment, the Northern Nitralloy and the Vickers balanced-gear, the differences in construction are mostly concerned with back thrust and its effects. Let us now take up these two types of gear pump, beginning with the Northern.

Northern Nitralloy Series 4000 Gear Pump

The Northern Nitralloy Series 4000 gear pump is not a single model of pump, but a whole variety of types. To withstand effectively the forces we have mentioned as typical of those developed in gear pumps (particularly those operating at considerable pressures), these pumps are ruggedly constructed of hardened steel so that the moving parts maintain their alignment and resist wear and leakage over long periods of use. Figure 5–4 shows the massive proportions of their bearings and other parts. This line of pumps is notable also for versatility and simplicity of construction.

The housing for the Northern Nitralloy series 4000 gear pump consists of five hardened alloy steel sections (fig. 5–4A), accurately machined and ground, and bolted together by four long bolts running through all the sections. The center block, or CYLINDER PLATE, forms the

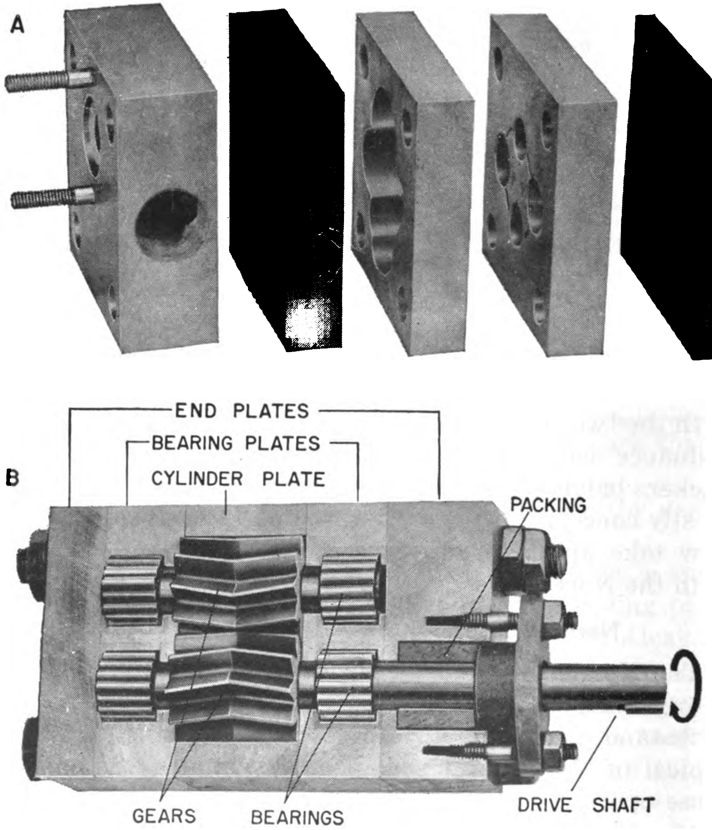


Figure 5–4.—Construction of Northern Nitralloy series 4000 gear pump. A. Sections (disassembled). B. Assembled (cutaway).

housing for the gears (fig. 5–4B). On each side of the cylinder plate are mounted the BEARING PLATES, which house the bearings on which the gear shafts rotate. Completing the assembly are two END PLATES. The one that receives the drive shaft contains the packing.

You'll find the Northern pumps of this type in many rammers (particularly in 5-inch mounts) and hoists. In these applications, the plain end plates illustrated in figure 5–4 are replaced by plates that incorporate mounting brackets or valve blocks necessary for the mechanism in which the pump is employed. Because of its sectional construction feature the pump is very versatile and relatively easy to assemble and disassemble.

Three types of gears may be used in the Northern Nitralloy series 4000 pump: SPUR, HELICAL, and HERRINGBONE. Figure 5–5 shows these types. The disadvantage of the spur type is that at high speeds and pressures some liquid is carried between the meshing teeth, forcing the gears apart. For this reason, spur-gear pumps are generally used only at low speeds and pressures. The helical (with slanting teeth) and herringbone (double helical with teeth meeting in herringbone pattern) types do not have this drawback because the teeth mesh gradually, forcing the trapped liquid out one side (in helical gears) or both sides (in herringbone).

Vickers Balanced-Gear Pump

The Vickers balanced-gear pump is really a dual-purpose device. It can be used either as a pump (for instance, in the 40-mm power drive) or as a hydraulic motor (in the 6"/47 rammer). It's also bidirectional; it can pump in either direction, depending on how it turns.

As far as pumping action is concerned, the Vickers balanced-gear pump works just the way the Northern series 4000 pump does. The distinctive feature of the Vickers is the way it handles the back thrust (fig. 5–3) from the fluid in the discharge line.

In the preceding section, we found that the problem of

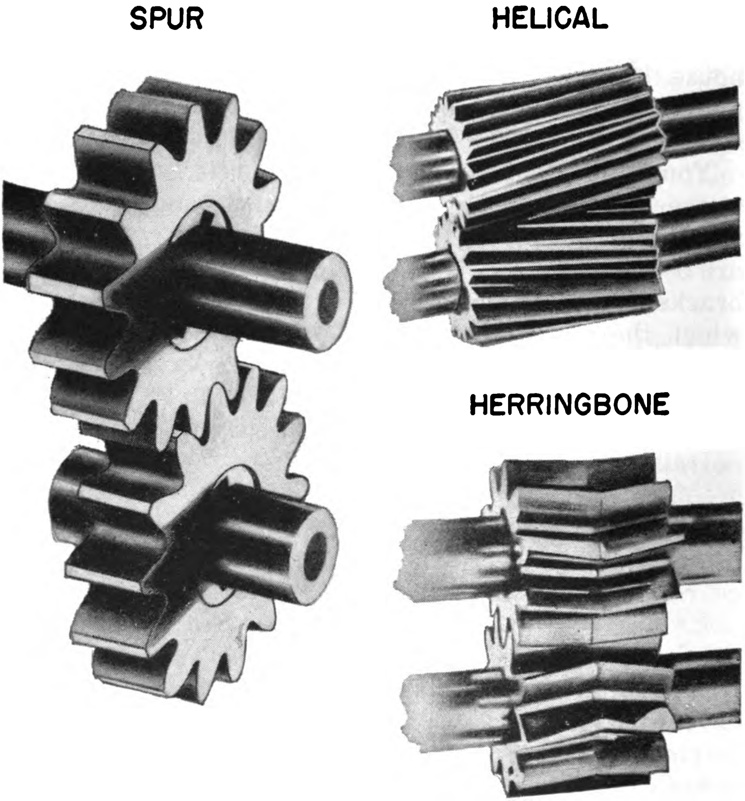


Figure 5—5.—Three types of gears may be used in the Northern Nitralloy series 4000 gear pump.

this thrust in the Northern gear pump is handled simply by increasing the physical strength of the pump—making the parts massive, broadening the bearings, and using an exceptionally strong alloy in the pump's construction. But the Vickers pump is of much lighter construction. Its housing is usually of cast steel or bronze, easily distorted by excessive thrust. Some other solution is necessary.

The solution is a unique design feature: a system of BALANCING LINES machined into the pump body (fig. 5–6A). Each line connects with the discharge side in such

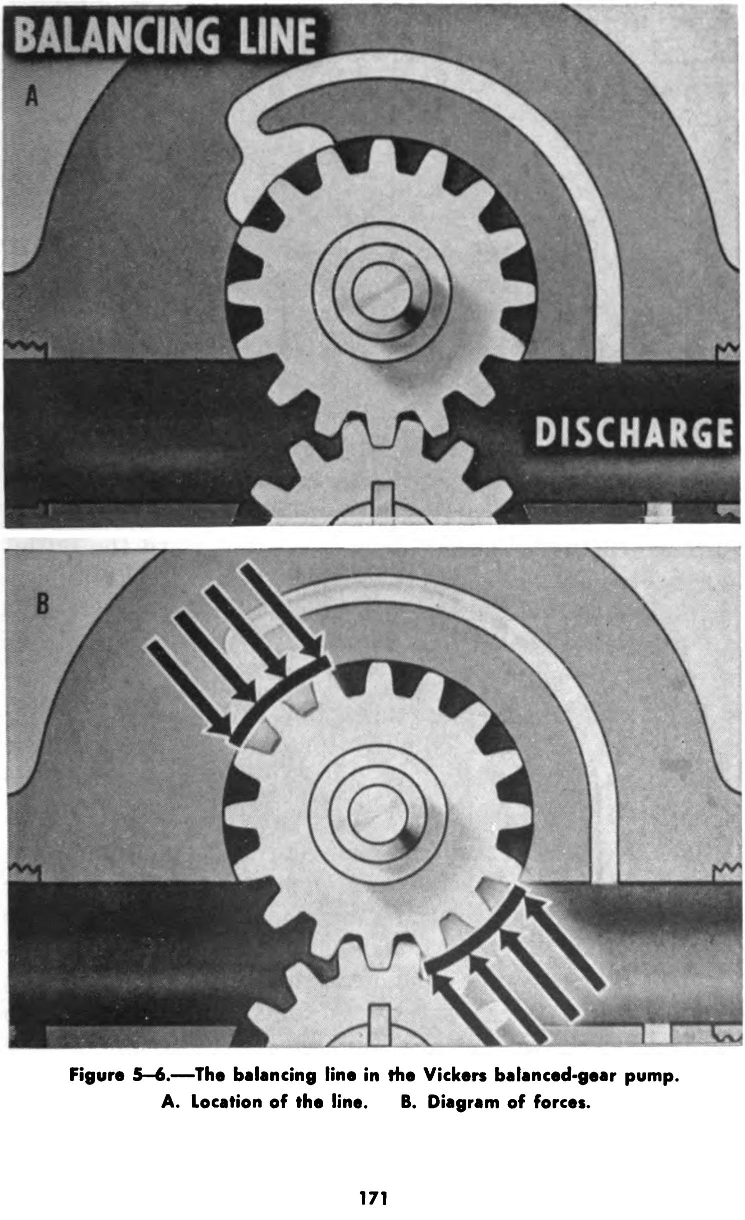


Figure 5–6.—The balancing line in the Vickers balanced-gear pump.
A. Location of the line. B. Diagram of forces.

a way that the opening of the balancing line is directly opposite the thrust area. When the pump is in operation, liquid fills this line. Whatever pressure is exerted against the gear at the discharge side is exactly duplicated in the opening of the balancing line opposite. This opening is equal in area to the area against which the thrust is exerted, so that EQUAL FORCES act on both sides of the gear (fig. 5–6B).

Naturally, though figure 5–6 shows but one gear and balancing line, there must be a line for each of the two gears. But that's not all. Earlier in this section we stated that the Vickers balanced pump is BIDIRECTIONAL. Each balancing line, however, can oppose pressure from only one direction. Therefore each gear must have TWO balancing lines, making four balancing lines in all (fig. 5–7).

In operating as a hydraulic motor, the Vickers balanced-gear pump is driven by hydraulic fluid under pressure which turns the gears as it flows toward the outlet side. The balancing lines, under these circumstances, simply oppose pressure exerted from the inlet side. So, as you can see, this unit can function as a motor in either direction.

The balancing lines, though they look pretty substantial in the schematic illustrations in this section, are actually tiny passages whose purpose is to maintain pressure balance, not to transmit volume.

As for construction, figure 5–8 shows the main components of the Vickers balanced-gear pump. Details like the balancing lines are not indicated in the figure. Like its Northern counterpart, the pump is simple in construction. The three main stationary units are the CYLINDER BLOCK within which the gears turn, and the two END PLATES which contain the bearings for the gear shafts. One shaft protrudes through one end plate to the outside, and this is the only one that requires packing. The Vickers gear pump uses spur gears.

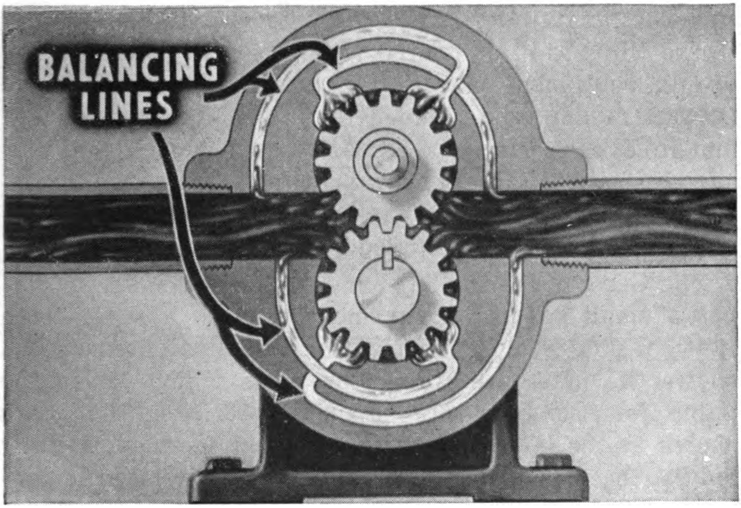


Figure 5–7.—The four balancing lines in the Vickers balanced-gear pump.

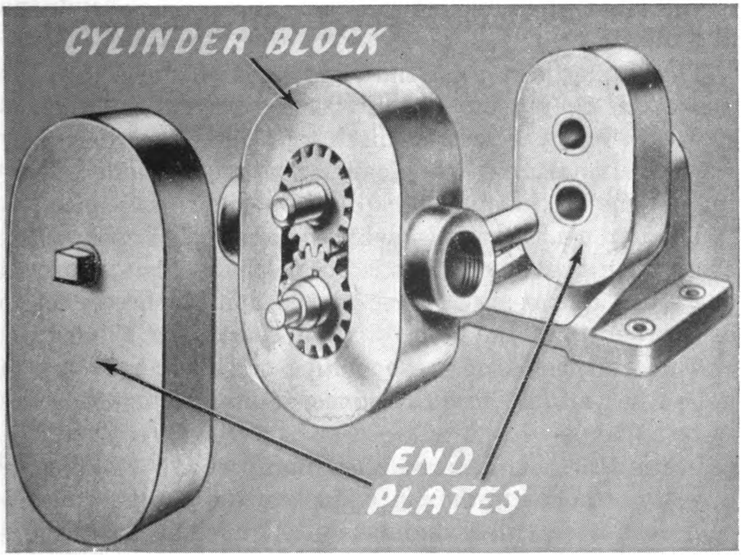


Figure 5–8.—Main components of the Vickers balanced-gear pump.

Two Internal-Gear Pumps

The third kind of geared pump used in ordnance hydraulic equipment that we take up in this course is the INTERNAL-GEAR type. One of these, the GEROTOR, you will find in 12-inch turret power drives and hoists, and as a hand-operated auxiliary on 5-inch ammunition hoists. Another, made by Northern, can be found on some Northern-built ammunition handling equipment.

The Gerotor (as the left-hand half of fig. 5–9A shows) has a small six-tooth gear meshing with a seven-tooth internal ring gear. The right-hand half of figure 5–9A shows the plate containing the ports which, when the pump is assembled, are superimposed over the gears shown at the left. Note that the gear teeth mesh fully only at the TOP of the pump, although they remain in sliding contact all around the pump. The spaces between them increase in size toward the bottom.

When the pump is running, the cavities or pockets between the teeth INCREASE in size as they move DOWNWARD at the right, then DECREASE in size as they move UPWARD at the left.

The intake port is at the right, and oil flows into the pockets as they grow larger. At the bottom the pockets move over to the left or discharge port side. As they rise with rotation of the gears, they grow smaller, forcing out the oil that they took in at the right.

The two gears travel slowly with respect to each other, even when the drive shaft is rotating rapidly. Thus, in one model the gears revolve at 200 rpm with respect to each other when the pump shaft is rotating at 1,800 rpm.

Various models of these pumps can deliver from 0.4 gallon per minute to 30 gallons per minute at pressures up to 1,000 psi.

In the Northern internal-gear pump (fig. 5–9B) a gear directly attached to the drive shaft of the pump is set off-center in a circular chamber fitted around its circumference with the teeth of an internal gear. The two gears

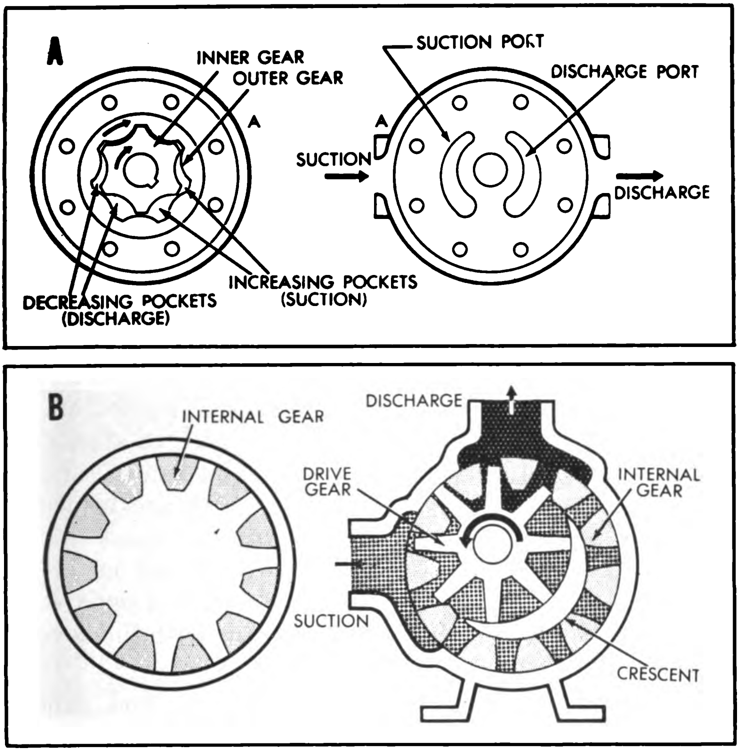


Figure 5–9.—Internal-gear pumps. A. Gerotor. B. Northern.

mesh on one side of the pump chamber, between the intake and the discharge. In the opposite side, a crescent-shaped part in the space between the two gears makes a close clearance with them.

The rotation of the central gear by the shaft causes the outside gear to rotate, since the two mesh. Everything in the chamber rotates except the crescent. Liquid trapped in the gear spaces as they pass the crescent is carried from the intake to the discharge, where it is forced out of the pump by the meshing of the gears.

The pump can be assembled with the crescent-shaped part on the opposite side. This reverses the fluid flow in the pump.

Vickers Balanced-Vane Pump

The rotary pumps we have studied up to this point have all depended for their operation on the meshing of two gears or lobes. Even the internal-gear pumps work on this principle, with the two gears one inside the other. The Vickers balanced-vane pump is different. It has only one rotating part, rather than two, and no gears at all.

You'll find rotary-vane pumps rather widely used in ordnance hydraulic systems, from 5-inch Vickers rammers and ammunition hoists to 16-inch projectile rings, elevating power drives, and powder hoists.

The basic construction of the Vickers balanced-vane pump is very simple indeed (fig. 5–10). Mounted on the drive shaft is the ROTOR, a cylindrical block of steel with 12 evenly spaced slots accurately machined in it. Snugly fitted into these slots are 12 vanes, which are blades of hardened steel. Though the vanes are not loose enough to rattle around, they are free to move in and out of the slots. The vanes have a beveled edge and a square-cut edge, and they are assembled in the rotor with the beveled edge trailing.

Surrounding the rotor is the hardened and ground RING, which is elliptical or oval in shape. The ring, in turn, is enclosed by the pump's outer case or HOUSING.

The sides of the pump are enclosed by two VALVE PLATE BUSHINGS, in whose sides are cut the intake and discharge ports.

Now let the rotor revolve at the pump's normal operating speed (1,200 rpm). What happens?

As you can guess from our discussion of centrifugal pumps earlier in this chapter, centrifugal force comes into the picture and the vanes in the rotor immediately try to fly out. Of course, the vanes can't actually get far, because they're confined by the elliptical ring. But, under the thrust of centrifugal force, they push hard against the inside surface of the ring, and can form an oil-tight seal. As the rotor turns, the vanes remain in contact and

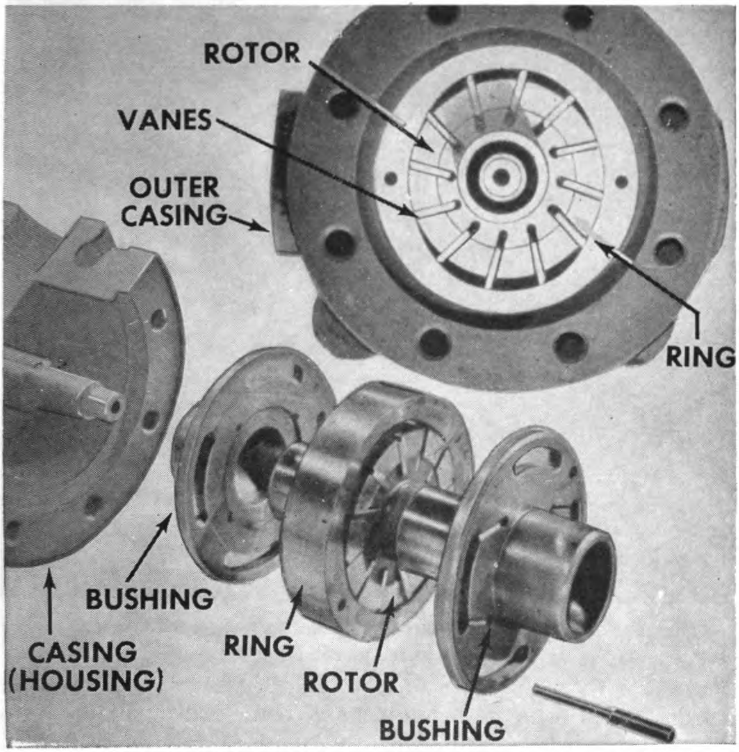


Figure 5–10.—Vickers balanced-vane pump (cutaway and exploded views).

follow the contour of the ring, sliding out of and into the rotor.

The ring's contour permits the vanes at the top and bottom to extend further than at the sides, where they are held all the way in. Thus, the vanes divide the space between rotor and ring into little spaces or chambers that change in size as the rotor turns. Figure 5–11 shows how the chambers expand as the rotor turns from A to B, then contract as they approach C, and so on around the ring.

This behavior of the vane pump calls to mind that of the Gerotor pump, discussed earlier in this chapter. The

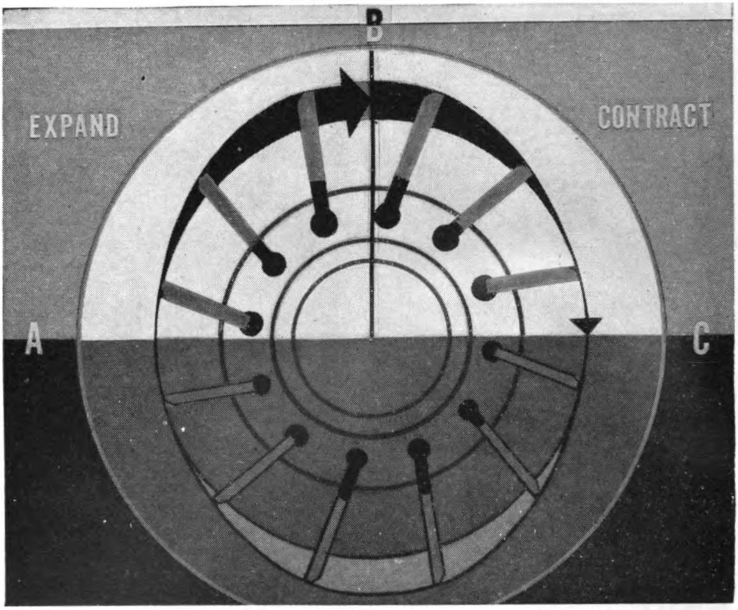


Figure 5–11.—How the chambers expand and contract in the balanced-gear vane pump.

difference here is that, whereas in the Gerotor the "chambers" expand and contract once each time the pump rotates, in the vane pump the chambers expand and contract TWICE per rotation.

Remembering the Gerotor, it's obvious that you put the intake where the chambers expand, the discharge where they contract (fig. 5–12A).

In the vane pump, as in the gear pumps we've studied, the ordnance hydraulics designer must take into account not only the flow of fluid through the pump but also the pressure relationships. And analysis will show that when the pump, as we have so far described it, is in operation, there is a heavy thrust on the discharge side and a lesser, but still considerable, thrust on the inlet side. Since these thrusts are unbalanced, they can strain bearings and distort the pump housing.

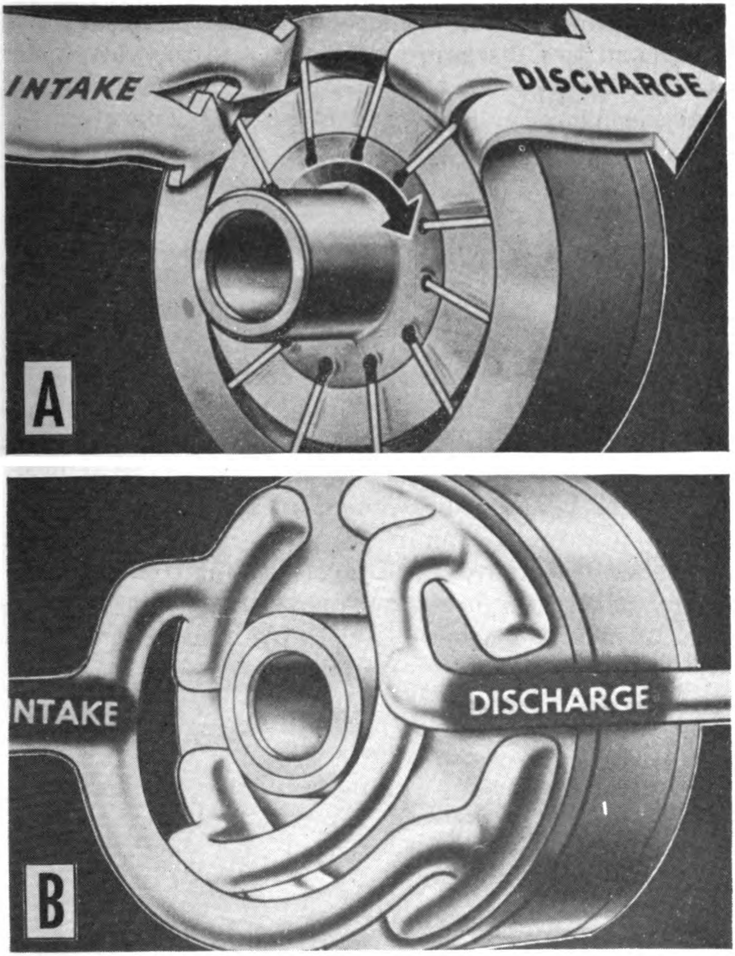


Figure 5–12.—Balanced-vane pump: intake and discharge.

As we learned from the Vickers balanced-gear pump, one thing to do with unbalanced pressures or thrusts is to balance them. This is done in the vane pump not by using balancing lines, but by putting the WHOLE pump to work, instead of only the upper half that you saw in figure 5–12A. Therefore, since the pump chambers expand and contract twice during each rotation, the pump has two intake and two discharge ports cut into the valve-plate bushings that cover each of its sides. The discharge and intake ports are paired, and the passages connecting the ports to their proper lines are arranged as in figure 5–12B. In the actual pump these passages are not separate tubes, as the figure shows them, but are cut into the pump housing.

The discharge ports are equal in area and under equal fluid pressure. The intake ports are similarly equal in area and fluid pressure. It logically follows, then, that the discharge sections on opposite sides of the pump exert equal balanced thrusts, as do the intake sections (though the thrust at each intake is much smaller). We have, as a result, all the thrusts balancing out, regardless of pressures in the intake and discharge lines (fig. 5–13).

When you closely examine the valve-plate bushings, you will notice two grooves or passages leading from each discharge port to tiny holes that pierce the bushing (fig. 5–14A). Tracing the flow of oil through these holes, you

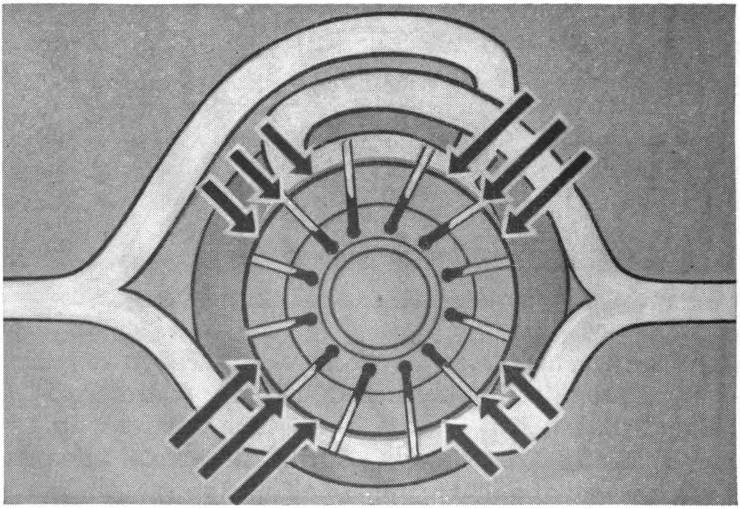


Figure 5–13.—Balancing of forces in Vickers balanced-vane pump.

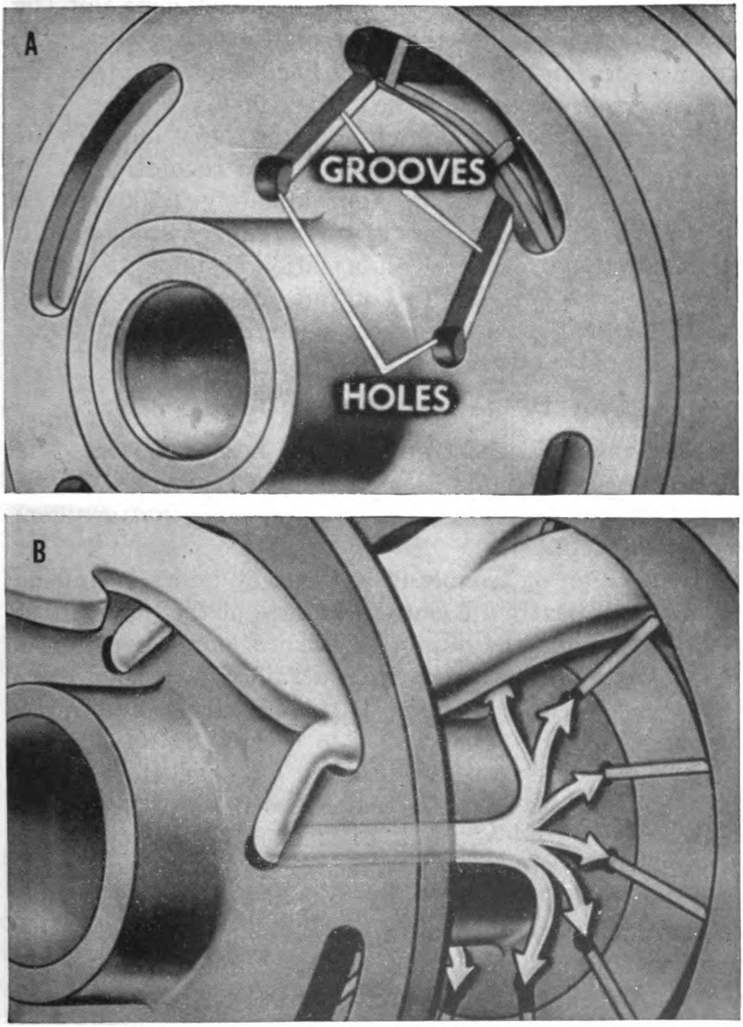


Figure 5—14.—Balanced-vane pump. Forced self-lubrication system.

find that it goes to a shallow annular (ring-shaped) recess or depression around the rotor, thence to the pinhead-shaped openings at the bottom of each vane slot (fig. 5–14B). (In actuality, the valve-plate bushing closely fits against the ring; in the figure it has been separated from the ring in order to show the path of flow.)

Since the vanes, though close fitting, must move in and out of their grooves twice during each revolution of the motor (and it rotates at approximately 1,200 rpm at normal speed) one purpose of this arrangement should be obvious. It's a forced self-lubrication system. It has another purpose too: The full output pressure of the pump is exerted at the base of every vane, helping centrifugal force to hold it outward against the ring.

Maintenance of Rotary Pumps

Since many of the troubles and their symptoms that develop in rotary pumps are similar, regardless of differences in type, let us first take up those that are common to all types.

A sure sign of trouble in any rotary pump is unusual noise. Frequently the cause is failure of the liquid in the system to reach the pump. Since the pump depends on the liquid for lubrication, such a failure will soon cause the pump to heat up, and parts are likely to bind or break.

Lack of liquid can be caused by low level in the tank, by clogged lines, or by oil that is too thick or heavy. If the oil is low, add enough to bring the level up to the prescribed amount. If it's thick or heavy, drain the system and refill with the proper type of fluid. You can find the proper type by consulting OD 3000 or the OP describing the equipment. As for clogged lines and filters—clean 'em. (See OD 3000 and the OP on the equipment for information on filters. *Basic Hydraulics* (NavPers 16193) and the Navy training courses for *Gunner's Mate 3* contain information on methods of cleaning hydraulic pipe and tubing.)

The pump may also fail to receive adequate fluid because of leaks in the intake line or excessive air in the system, or because it's not turning in the right direction at the right speed. Air leaks cause characteristic hammering noise, and often make relief valves chatter. Be sure to check gaskets, seals, and tubing on the intake side of the pump, and to replace faulty or leaky parts. Check the name plate on the pump to verify the proper pump speed.

Remember that the pump may run too slowly as well as too fast. Slow running may prevent the pump from receiving fluid; fast running will result in excessive noise, strain, and wear. Remember also that the name plate shows the one and only right direction in which the pump shaft is supposed to turn; make sure it's turning that way, or it won't pump.

Noisy operation may also indicate misaligned couplings, with resultant excessive wear on bearings and packing. The motor and pump shafts must be lined up in the same straight line. If they're not, realign them and replace bearings and packing.

Lastly, wear will cause vibration, leakage, and lowered efficiency. When that happens, you'll have to replace worn or broken parts.

Maintenance of the Vane Pump

In addition to the above, there are a few special pointers on the vane pump that you should be acquainted with.

In general, installation and maintenance of the Vickers balanced-vane pump are largely the same as for other rotary pumps we have taken up. But direction of rotation is particularly important. To make sure you don't have trouble with this, see to it that the rotor is fitted into the ring so that the arrows on the rotor and the valve-plate bushings head the same way as the arrow on the pump housing. Otherwise, vanes and rotor will break. Similarly, make sure that the drive shaft turns in the direction of the arrow on the housing.

The chief symptoms of trouble in the vane pump are:

1. Failure to deliver liquid
2. Noisy operation
3. Overheating
4. Leakage

Noisy operation, failure to deliver, or overheating may be caused by low fluid level, wrong direction of rotation, clogged lines or filters, air leaks in the input line, fluid too heavy, or operation at too low a speed. We've encountered these symptoms in connection with other rotary pumps.

The vane pump can also have troubles peculiarly its own, however. The vanes may stick because of dirt or chips in the fluid, or because of using too heavy a fluid. As a result, you'll get noise, overheating, and, pretty soon afterward, a broken shaft or rotor. The cure is to remove the pump, replace damaged vanes, and use clean hydraulic fluid of the proper type.

The pump can also give trouble because the vanes have not been correctly assembled in the rotor. The thing to remember when assembling vanes is that THE TRAILING EDGE IS THE BEVELED EDGE.

There's a considerable amount of packing in the vane pump, and leakage indicates that it needs replacement. Faulty gaskets can cause noise too, as can misaligned couplings.

RECIPROCATING PUMPS

The reciprocating pump (so called because its parts must reciprocate, or move back and forth, to function) was the earliest type to be used commonly in hydraulic systems ashore and afloat. Most reciprocating pumps consist fundamentally of a PISTON that moves back and forth in a CYLINDER fitted with CHECK VALVES. The valves open and close ports to a source of liquid and to the work area.

Reciprocating Pumps Using Check Valves

A common kind of arrangement for a reciprocating pump is like that shown in figure 5–15A. Both valves

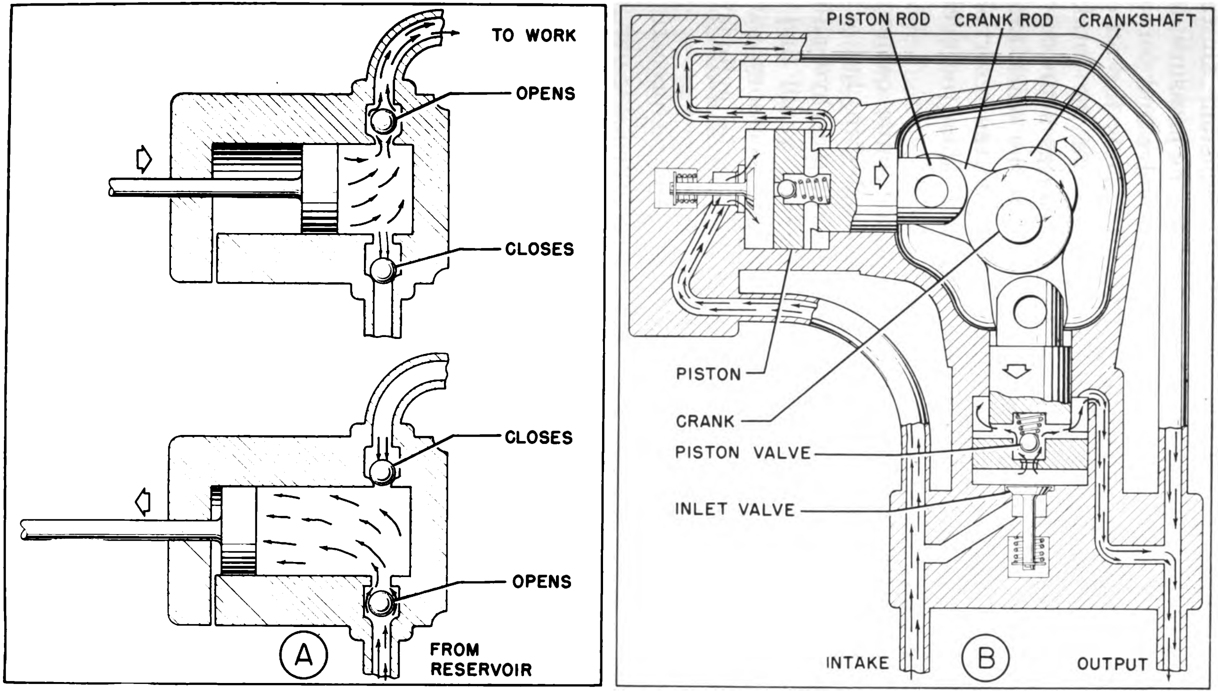


Figure 5–15.—Two types of reciprocating pumps equipped with check valves.

are in the cylinder on the same side of the piston. On the output stroke (upper half of fig. 5–15A) the pressure developed by the piston thrust opens one valve and forces fluid through it to the work, and also closes the other valve. As the piston reverses direction on the intake stroke (lower half of fig. 5–15A), it causes a pressure drop. The relatively higher pressure in the work area closes the outlet valve, and the valve from the reservoir opens to admit a fresh charge of fluid. Then the cycle repeats.

Reciprocating pumps of this type are quite common ashore and in many applications aboard ship, but you won't find many of them in modern ordnance hydraulic systems. There are a few; for instance, you'll find a hand-operated pump of this type as an accessory with larger gun mounts, for recharging differential cylinders with fluid.

Figure 5–15B shows another variety of reciprocating pump equipped with check valves. You'll find this one on many 5-inch dredger ammunition hoists as a manually operated hydraulic unit for operating the hoist by hand.

The unit, illustrated in cutaway schematic form, consists of two pump cylinders mounted at right angles, with their pistons connected through piston rods and crank arms to a single crank, whose shaft is operated by a large external hand crank (not shown). The two cylinders are identical. Each has two valves—one in the piston and one in the cylinder head. In the illustration, the horizontal piston and piston rod are shown in the midst of their down (leftward) stroke. The valve in the piston is closed, and the fluid in the cylinder left end is being forced out to the work area. At the same time at the right end of the cylinder, the valve in the cylinder head is open to admit fluid from the intake line.

The upright cylinder is shown at the top of its upward stroke. The inlet valve in the cylinder head is still closed, and the piston valve is open, permitting the fluid above the piston to pass through to the area below. As the pump crankshaft continues to turn, the piston valve will close and the inlet valve will open, and the cylinder action will duplicate that of the horizontal cylinder—which in turn will continue the cycle by repeating the function just described for the upright cylinder. Since the pump cylinders are connected in parallel, this "staggering" makes the output smoother.

Reciprocating Sump Pump and Oscillator

The last type of reciprocating pump we shall take up does not use check valves, but it's about the only power-driven reciprocating pump you're likely to see actually installed in ordnance hydraulic machinery. It's the SUMP PUMP AND OSCILLATOR (fig. 5–16) in the Ford power drive on 5"/38 twin mounts. Let's discuss this pump briefly.

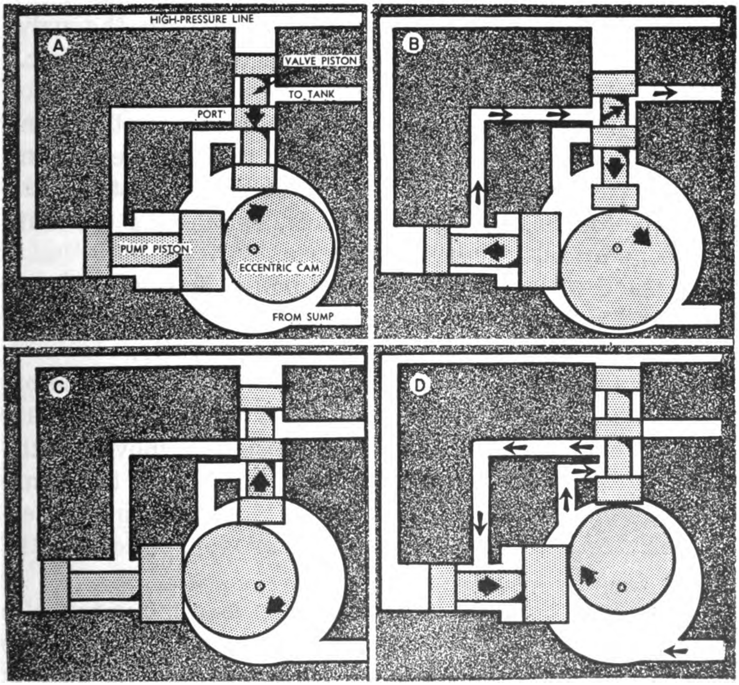


Figure 5–16.—Functioning of the eccentric cam piston pump and oscillator.

Like all other reciprocating pumps, this one requires valves in order to function. But instead of the check valves used in other reciprocating pumps we have discussed, a spool-type valve piston, driven by an eccentric cam that also drives the pump piston, opens and closes the pump's single port, which functions for both intake and output. The eccentric cam is driven through gearing by the main electric motor for the power drive.

Note in figure 5–16, the high-pressure line with which both the pump piston and the valve piston have contact. Remember however, that there is NO FLUID FLOW between the high-pressure line and the sump pump itself.

Now let's observe the functioning of this pump, beginning with the end of the intake stroke (fig. 5–16A). The valve piston is on its way down, and is shown blocking the pump's port. The eccentric rotates clockwise. Pressure from the high-pressure line keeps both the valve piston and the pump piston in contact with the eccentric.

In the eccentric's next quarter turn, the valve piston is at the bottom of its stroke, where it uncovers the pump port and opens the passage to the hydraulic system's tank or reservoir. (See fig. 5–16B.) At the same time, the pump piston is moving to the left, exhausting the fluid in the pump out through the port.

As the eccentric continues to turn, it drives the pump piston to the end of its exhaust stroke, and pushes the valve piston up to block the port (fig. 5–16C).

In the third quarter turn (fig. 5–16D) the valve piston, in extreme high position, has opened the port to the fluid around the eccentric. As the pump piston moves to the right in its intake stroke, fluid flows in from the sump through the passages at the lower right, around the eccentric, and into the port. After this step, of course, the whole cycle is repeated.

This mechanism functions not only as a pump but also as an OSCILLATOR; that is, as the valve and pump pistons reciprocate, they agitate or jiggle the hydraulic fluid in the system so that the fluid is in a state of continuous vibration. This vibration makes the system's components respond more quickly and tends to reduce friction and sticking of valves and pistons.

In later mods of this mechanism the valve piston is not connected to the high-pressure line, but instead is spring-loaded to keep it in contact with the eccentric. Only the pump piston acts as an oscillator.

A-END AND B-END

Hydraulic systems have many functions in modern United States naval ordnance—control of recoil energy, operation of the rammer, hoisting and feeding of ammunition, and so on—but the most complex and exacting of these is that of positioning the gun. The hydraulic systems used for training and elevating the gun are, therefore, more complex than any of the others you will find around the gun mount.

A hydraulic training or elevating system can be divided into two main parts, one corresponding to a man's nerve system, the other to his muscle. The control system, or "nerve system," is the INDICATOR REGULATOR, taken up elsewhere in this course. The "muscle" is the HYDRAULIC SPEED GEAR or POWER DRIVE.

Let's look at the main components of the hydraulic speed gear in a common present-day installation—the 5"/38 twin mount. Figure 5–17 shows the components

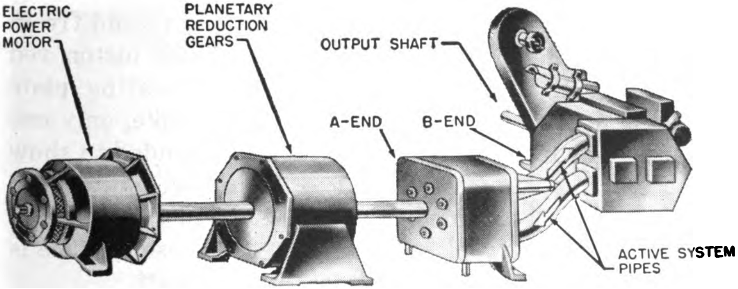


Figure 5–17.—Hydraulic speed gear of 5"/38 twin mount. Main components (schematic).

for either a train or an elevation power drive. At the left is the electric power motor, which furnishes to the mount all the energy used in training or elevating. Since the motor runs at 3,495 rpm and the hydraulic A-END pump it drives is designed to run at 900 rpm, the motor is coupled to the pump through a set of PLANETARY REDUCTION GEARS. The pump's hydraulic output drives the B-END, a hydraulic motor. The B-end, in turn, drives the gears that actually elevate or train the mount. It is the A-end and B-end with which we're concerned in the rest of this chapter.

The hydraulic pump and motor that constitute the A-end and B-end are AXIAL-PISTON units. The A-end is a POSITIVE-DISPLACEMENT VARIABLE-DELIVERY PUMP. Though it runs at a constant speed of 900 rpm, its output can be varied from maximum to zero, and it can pump fluid equally well in either direction, depending on how it is set. The speed and direction of the B-end hydraulic motor's operation depend entirely on A-end output. The pumping action of the A-end therefore regulates the performance of the B-end with great accuracy. The hydraulic fluid in the system circulates from A-end to B-end and back through the ACTIVE SYSTEM pipes.

Because it's somewhat simpler than the A-end, let's examine the B-end (motor) first (fig. 5–18).

The B-end has an odd number of CYLINDERS in a CYLINDER BLOCK or CYLINDER BARREL, arranged parallel to the motor's shaft or axle, with a piston moving to and fro in each (hence the name AXIAL-PISTON). Each piston rod is linked by a ball-and-socket joint to a rotating plate called the SOCKET RING. (For simplicity's sake, only one piston is shown in figure 5–18, which is intended to show only the principle of the B-end.) The socket is linked to the shaft of the machine by a UNIVERSAL JOINT, and bears against a stationary plate (TILT PLATE) whose surface is tilted at a fixed angle with respect to the shaft.

Now we'll apply hydraulic pressure and see what happens.

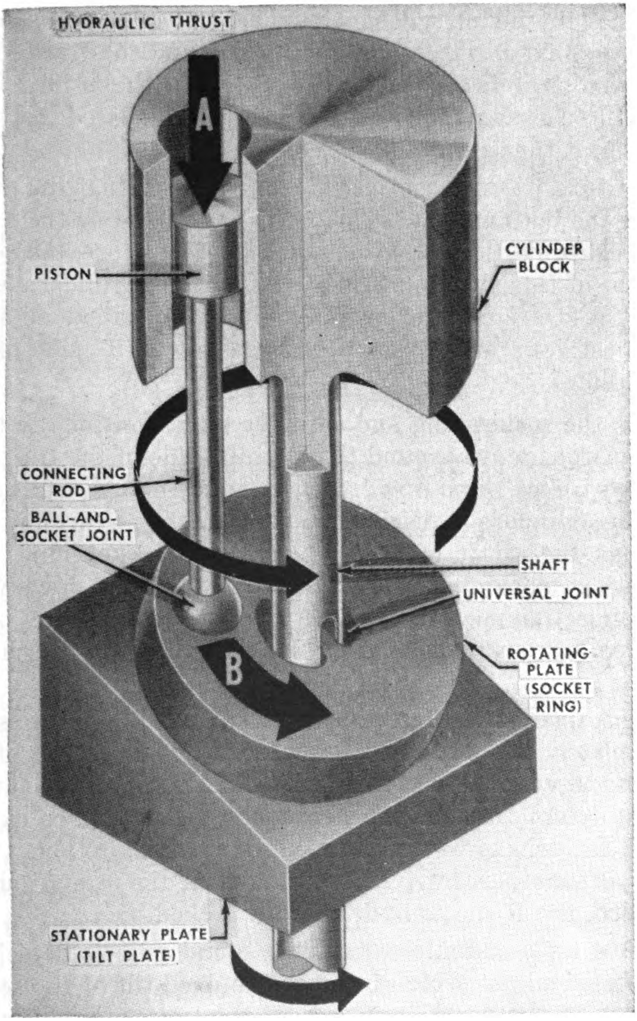


Figure 5–18.—Principle of the B-end.

Hydraulic pressure causes the piston to exert a thrust (arrow A) against the tilted socket ring. The socket ring can yield to this thrust only by moving "downhill," so that the piston will move downward. Since the socket ring is linked to the shaft, both plate and shaft are forced to turn as indicated by arrow B. And that's how a hydraulic thrust parallel to the axle is translated in the B-end into turning effort or TORQUE.

Naturally, once the socket ring turns so that the piston is at the bottom of its stroke, thrust exerted by the piston can cause no further turning effort. Therefore, the actual B-end of this system has not one but nine cylinders, evenly spaced around the cylinder block, so that at all times at least four are working on the "downhill" side of the tilt plate.

As the socket ring and cylinder block continue to turn, the pistons move around the "uphill" side of the tilt plate, which forces them upward again, and the hydraulic fluid in the cylinders is discharged into another hydraulic line. So, as the shaft, cylinder block, and socket ring keep rotating, some pistons are always pushing downward, keeping the machine in motion, and others are being forced upward, exhausting their fluid into a discharge line.

The speed and direction in which the B-end turns are completely and precisely determined by the output of the A-end to which it is connected. This is an exact relationship, except for a slight discrepancy that may be caused by B-end leakage—which amounts normally to about one-half of one percent. Moreover, when the A-end output is zero, the B-end is hydraulically locked.

Now let's examine a complete B-end (fig. 5–19). Note the broken lines which indicate the fixed tilt of the socket ring. At the right-hand end of the unit, secured to the rest of the B-end housing, is the VALVE PLATE, containing two semicircular VALVE-PLATE PORTS. These admit fluid to or exhaust fluid from the CYLINDER PORTS (one per cyl-

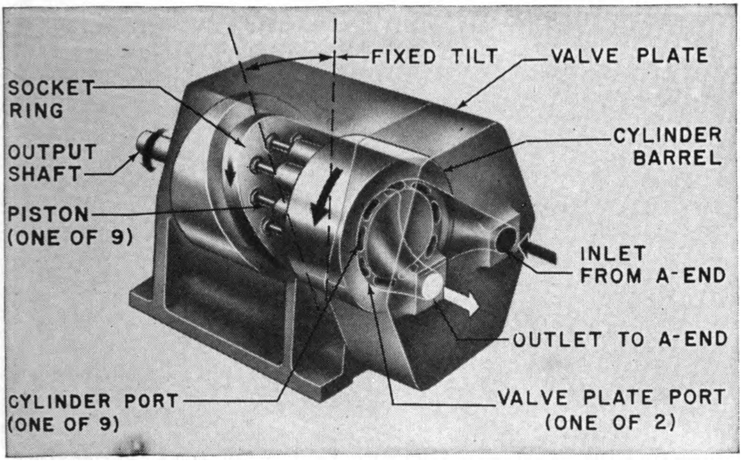


Figure 5–19.—B-end (phantom view).

inder) in the cylinder block, depending on the direction of A-end output. (In the figure, fluid is entering the right-hand valve-plate port and exhausting from the left, driving the B-end counterclockwise. If the A-end output were in the opposite direction, the B-end would rotate clockwise.) Certain details of the B-end, like the thrust bearing and universal joint, are not shown in figure 5–19.

Can you see why the axial-piston B-end (and the A-end as well) has an odd number of cylinders? Notice how, as each cylinder port moves across the "blind spot" separating the two valve ports, flow of hydraulic fluid into or out of the cylinder is blocked. If the cylinder barrel contained an even number of equally spaced cylinders, two cylinders would be blocked at the same time, one at the top and one at the bottom of the barrel. The interruption would cause a shock to the hydraulic system. With an odd number of cylinders, only one cylinder is blocked at a time, and this shock effect is minimized.

The A-end is like the B-end both in operating principles and in construction (fig. 5–20). Of course, since it's a pump, it's driven by an electric motor. The feature

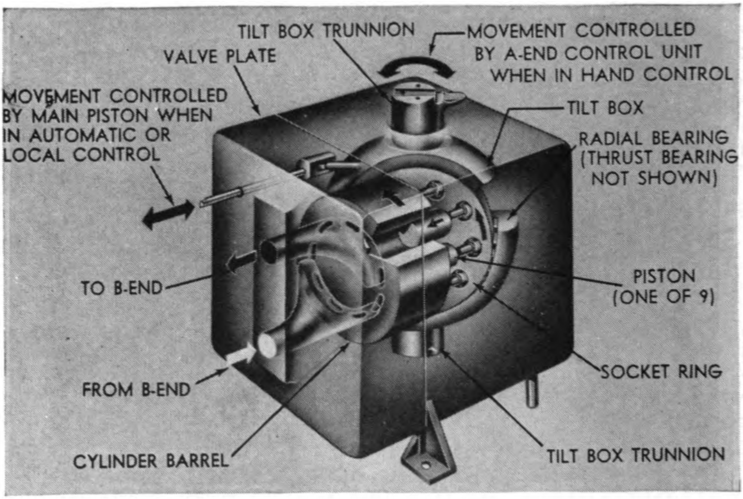

TILT BOX TRUNNION
VALVE PLATE
MOVEMENT CONTROLLED BY A-END CONTROL UNIT WHEN IN HAND CONTROL
MOVEMENT CONTROLLED BY MAIN PISTON WHEN IN AUTOMATIC OR LOCAL CONTROL
TILT BOX
RADIAL BEARING (THRUST BEARING NOT SHOWN)
TO B-END
PISTON (ONE OF 9)
SOCKET RING
FROM B-END
CYLINDER BARREL
TILT BOX TRUNNION

Figure 5–20.—A-end (phantom view).

that differentiates it from the B-end is the MOVABLE TILT PLATE or TILT BOX.

You saw in figure 5–19 that the tilt plate in the B-end is fixed. But in the A-end the tilt plate can be positioned about the TILT BOX TRUNNION. (See fig. 5–20.) The tilt can be varied within 20 degrees in either direction from zero. It is the tilt-plate angle that determines both the quantity and the direction of the A-end output.

If the tilt-plate angle is large (fig. 5–21A), each piston will slide deep into its cylinder and drive a large amount of oil through the lower line to the B-end. As the tilt-plate angle is decreased (fig. 5–21B), the piston strokes become shorter and less oil is pumped. When the tilt is zero (tilt plate parallel with cylinder block, as in fig. 5–21C), the length of the piston strokes has been reduced to zero and no oil is pumped.

The output of the A-end is reversed by slanting the tilt plate in the opposite direction, as shown in figure 5–21D. Then the oil is pumped into the upper line, to flow under pressure through the corresponding pipe to the B-end,

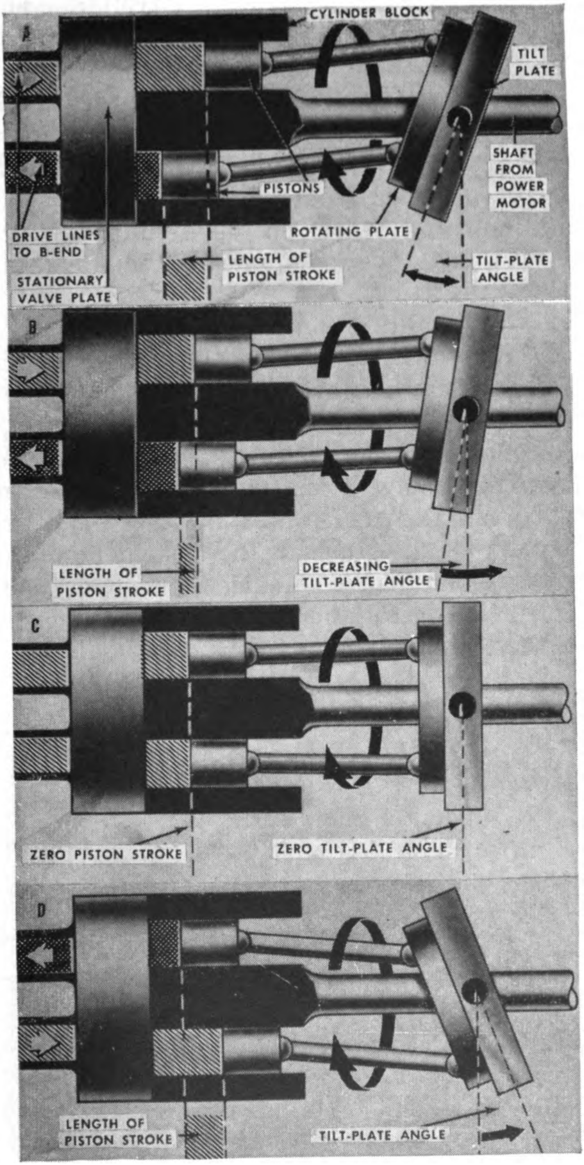


Figure 5–21.—Effect of tilt-plate angle on A-end output.

which then rotates in the opposite direction. The tilt-plate angle again determines the quantity of the output.

Though the VOLUME of oil pumped from A-end to B-end governs B-end speed, the requirements of the load dictate oil PRESSURE. Thus, if the load on the B-end increases, a higher B-end input pressure is required. This means higher input pressure from the A-end. To produce it, the torque (turning effort) on the A-end must increase. This increase in torque is supplied automatically by the power motor.

Figure 5–22 shows in simplified form how the A-end and B-end work together to drive the mount. One A-end and one B-end only are used in one system. The same oil is recirculated through the single closed system. The figure doesn't show the RELIEF VALVES that protect the A-end against damage from excessive pressure in case the B-end jams, the REPLENISHING VALVES and REPLENISHING PUMP which return to the system liquid lost by leakage, or the mechanical linkages and hydraulic components which control the system by varying the tilt angle of the A-end tilt plate.

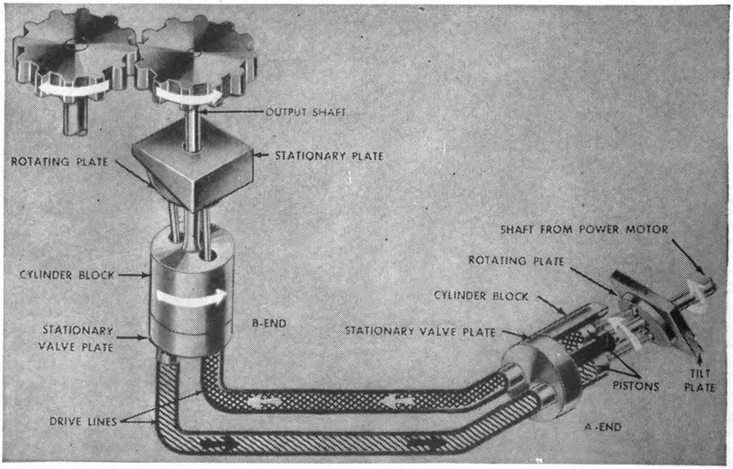


Figure 5–22.—A-end and B-end working together.

Waterbury and Northern A-ends and B-ends

Now that we have discussed the principal features of functioning and construction of axial-piston pumps and motors, let's consider in more detail the three main varieties that you will encounter as a Gunner's Mate.

The axial-piston units used in ordnance hydraulic systems are made by Waterbury, Northern Ordnance (formerly Northern Pump and Machinery), and Vickers. In the preceding section, our discussion centered around the Waterbury. You'll find nine-cylinder Waterbury A-ends and B-ends in many 16-inch, 14-inch, 12-inch, 8-inch, and 6-inch turrets. Northern Pump units are also widespread in the same heavy-duty type of turret service; they drive many 6-inch, 8-inch, 14-inch, and 16-inch turrets. In general, Waterbury and Northern Pump axial-piston units are very similar in construction. There exist, in fact, turret installations in which training gear is powered by Northern and elevating gear by Waterbury equipment. All 5"/38 mount power drives now in use have either Waterbury or Northern hydraulic gear.

In Northern and Waterbury axial-piston pumps and motors, a spring holds the cylinder block or barrel firmly against the valve plate when the unit is not functioning. Hydraulic pressure holds them together when the unit is in operation.

The pistons and cylinders are ground and lapped to a smooth working fit, so that no packing is necessary. Narrow, shallow grooves are cut around the pistons to interrupt leakage and trap dirt, and to give the pistons hydraulic balance. The face of each piston has a small hole bored through it. This hole connects to the piston socket bearing, to lubricate the bearing.

Connecting rods join the pistons to the socket ring. The rods have spherical ball ends, forming a ball-and-socket joint with the socket ring, thus permitting the pistons to move freely in their cylinders. Through the whole length of the connecting rod is a small hole which

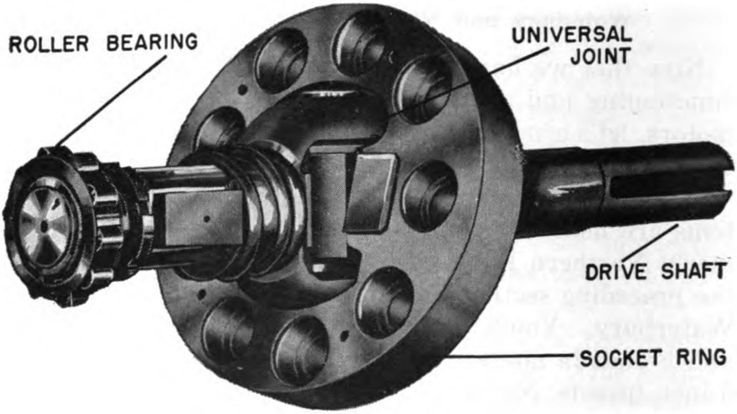


Figure 5–23.—Universal joint, socket ring, and drive shaft of Waterbury A-end.

feeds oil, under pressure, from the hole in the piston to the ball-and-socket joint.

Figure 5–23 shows how the socket ring is connected to the drive shaft through the universal joint.

Vickers A-ends and B-ends

Vickers axial-piston pumps and motors, on the other hand, are small seven-cylinder units used for elevation and train power drives in some 40-mm mounts, and in certain ammunition hoists.

The Vickers axial-piston unit (fig. 5–24) works in accordance with the same basic principles as the Waterbury and Northern type, but the construction is different in several ways. The two most important construction differences are:

1. Waterbury and Northern control the volume and direction of flow by changing the degree and direction of tilt of the A-end tilting box. With Vickers this is done by pivoting the cylinder block to either side of a neutral position. The cylinder block and valve plate are housed in a casting called a YOKE. The yoke can be swung on a pair of hollow PINTLES (pivots) (fig. 5–25).

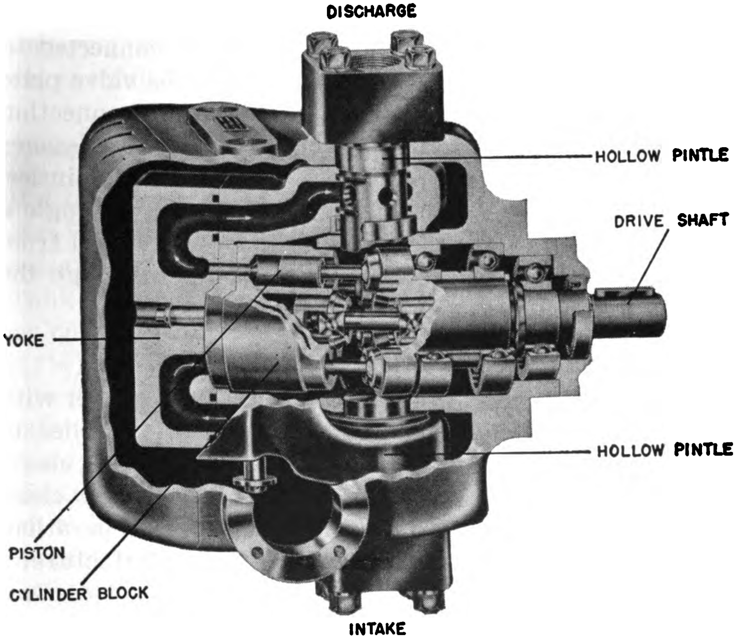


Figure 5–24.—Vickers axial-piston pump (cutaway), showing fluid flow path.

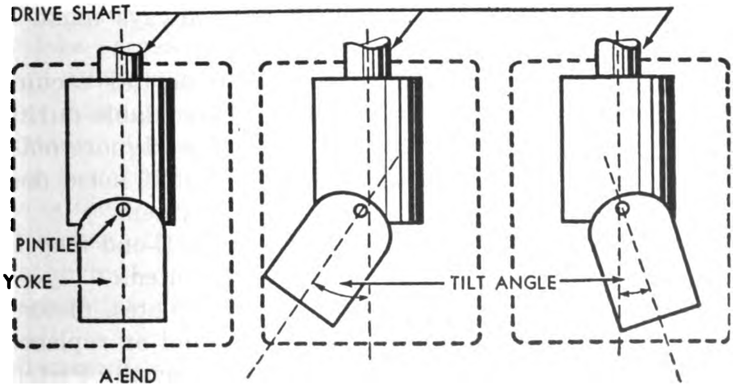


Figure 5–25.—Vickers axial-piston pump. How the yoke (containing the cylinder block) is pivoted on pintles.

2. In Waterbury and Northern pumps and motors the main transmission lines are directly connected to the valve plate. But in Vickers units the valve plate moves from side to side, and this direct connection cannot be made. So the yoke is cast with passages leading from the cylinders to the hollow pintles. The fluid flows in through one pintle, through a passage in the yoke to the cylinder block, and from the cylinder block out another passage through the other pintle (fig. 5–24).

Maintenance of Axial-Piston Pumps

In general, what we've said earlier in this chapter with respect to maintenance of other pumps also applies to axial-piston units, but more so. Take, for instance, cleanliness. Axial-piston pumps require an extremely clean hydraulic system for completely satisfactory operation.

The fluid used should conform to the manufacturer's specifications, and must be clean. It should not contain any light volatile oils to vaporize and leave gas or air pockets. For the same reason, the fluid should completely fill the active parts of the mechanism. Open the air valves one or two turns during filling, so that air can escape through them. Afterwards those valves must be kept tightly closed. A supply of fluid always must be maintained in the oil expansion box.

A pounding or rattling noise due to partial vacuum produced in the active fluid may be unavoidable during high-speed operation or under heavy loads. Ignore noise if it stops when the load is reduced. But if noise does not stop, air needs to be vented from the system.

Noisy operation or jerky motion of the B-end may be due to air in the system. It should be vented.

If foreign matter has scored the valve plates, pistons, or cylinders, they may need to be reground or replaced. The cause of the scoring must also be removed. Pistons may seize if improperly fitted, and may have to be replaced, or reground. The clearances are so small that pistons will work properly only if placed in the right cylinders. When you disassemble the units, mark all parts carefully, so that they can be replaced properly.

SUMPS, TANKS, RESERVOIRS, AIR CHAMBERS, AND ACCUMULATORS

We lump the items in this heading for convenience. Their functions are not very complicated, but they are necessary parts of hydraulic systems all the same.

Tank and reservoir mean pretty much the same thing. They contain reserve or excess supplies of hydraulic fluid. But they have other functions too. They are usually the points through which the system must be filled, and are usually located at the highest point of the system. In most systems they are not sealed off from the air; they must be vented (usually through openings containing fine wire mesh to keep dirt out). And, as EXPANSION TANKS, they provide room for the fluid to expand without overflowing out of the system.

As you already know, the SUMP is a collection point for overflow and leakage fluid, and it's at the lowest point in the system so that the fluid will flow into it. The SUMP PUMP picks up the fluid and returns it to the reservoir or tank. We have already discussed a reciprocating sump pump. Most other sump pumps are rotary types (usually lobe or gear).

AIR CHAMBERS are used in hydraulic systems to reduce water hammer and as "returning couples" to position hydraulic mechanism components. The mechanism you know best that uses an air chamber for the latter purpose is the counterrecoil mechanism of naval guns 5-inch and larger. The compressed air functions more or less as a spring—though it is not subject to the structural deterioration (called "fatigue") that causes metal springs to fail.

ACCUMULATORS are tanks in which the oil is stored under pressure. The upper part of the tank contains compressed air or nitrogen, and the pressure (by Pascal's Law) is transmitted throughout the liquid in the tank. (See fig. 5–26.)

Accumulators make possible the smooth delivery of hydraulic fluid even if there are violent pulsations or fluctuations in the input pressure. A surge of high pressure into the accumulator, for example, is not transmitted unmodified to the outlet. The air in the accumulator head can absorb the energy of the surge by compression. If on the other hand there is a sudden drop in pump pressure, the pressure in the accumulator prevents an abrupt drop in pressure at the outlet.

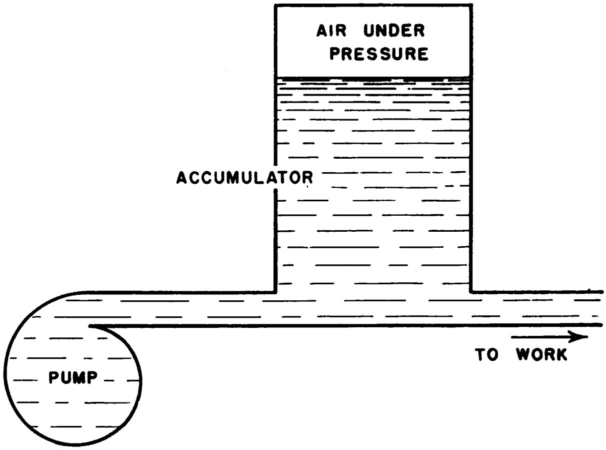


Figure 5–26.—Accumulator (schematic).

Accumulators are particularly valuable because they can store energy. In hydraulic systems for gun breech and loading mechanisms (like those in 6-inch and 8-inch turrets), the accumulators store enough energy to complete the cycle of operation if the electric power supply or the pumps fail.

SUMMARY

In this and the preceding chapter you have been introduced to the principal components of ordnance hydraulic systems. In other chapters you will see how these elements are combined to work with electrical, electronic, and mechanical elements to make up the precision machinery that controls the positioning and the fire of modern naval ordnance weapons.

QUIZ

In the following two questions, select the one BEST answer.

1. Which of the following features is not found in all pumps?
   a. Valves
   b. Inlet
   c. Outlet
   d. Pump chamber
2. The purpose of a sump pump is to
   a. prevent oil leakage from the hydraulic system
   b. return leakage oil to the tank
   c. maintain pressure in the high-pressure lines
   d. drain oil into the sump
3. Match the terms in column A, which describe types of pumps, with the explanations in column B.

Column A	*Column B*
(1) Positive displacement	(a) Quantity of liquid discharged by the pump can be varied without changing the speed of pump rotation
(2) Constant delivery	(b) Discharge of liquid in a continuous flow
(3) Nonpositive displacement	(c) Discharge of liquid in fixed amounts
(4) Variable delivery	(d) Quantity of liquid discharged cannot be varied unless the speed of rotation of the pump is varied.

In the following questions, select the one BEST answer.

4. All the rotary pumps taken up in this chapter
   a. depend on centrifugal force as their principle of functioning
   b. are of the variable-delivery type
   c. are positive-displacement units
   d. use meshing gears as their main elements
5. In which of the following types of pumps do you find small channels that do not materially contribute to pump output but do equalize thrust on the operating parts?

a. Northern Nitralloy
b. Vickers balanced-gear
c. Gerotor internal-gear
d. Vickers balanced-vane

6. In which of the following types of pump are ALL the gear teeth ALWAYS in contact with teeth in the meshing gear?
   a. Northern Nitralloy
   b. Vickers balanced-gear
   c. Gerotor internal-gear
   d. Vickers internal-gear

7. The balanced-vane pump is so called because
   a. the thrusts developed against the rotor from the intake and discharge ports are balanced on all sides
   b. the vanes must be balanced on their beveled sides before installation
   c. the centrifugal force exerted by the vanes is always balanced by the hydraulic pressure in the forced self-lubrication system
   d. the pump has no gearing thrust problems

8. Which of the following difficulties is LEAST likely to cause excessively noisy operation of a rotary pump?
   a. Pump running at too high a speed
   b. Pump running at too low a speed
   c. Air leak in pump intake line
   d. Misaligned couplings

9. In the Ford power drive sump pump and oscillator, the outlet and intake port is opened and closed by a
   a. check valve in the pump cylinder
   b. check valve in the pump piston
   c. cam-operated valve piston
   d. cam-operated check valve

10. Which one of the following parts of an axial-piston A-end does not rotate?
    a. Cylinder block
    b. Tilt plate
    c. Socket ring
    d. Connecting rod

11. Which of the following parts of an axial-piston pump both rotates and moves back and forth (oscillates) parallel to the pump's axis of rotation?
    a. Cylinder block
    b. Tilt plate
    c. Socket ring
    d. Connecting rod

12. The axial-piston pump delivers zero output when
   a. the tilt plate is parallel to the axis of rotation
   b. the tilt plate is parallel to the valve plate
   c. the valve plate is at maximum tilt
   d. the valve plate is tilted for zero piston stroke
13. In which of the following is hydraulic fluid always stored under pressure?
   a. Sumps
   b. Expansion tanks
   c. Reservoirs
   d. Accumulators

CHAPTER 6

THE FIRE-CONTROL PROBLEM

WHAT IS IT?

By this time in your career as a Gunner's Mate, you know that the term "fire control" as it's applied in gunnery has nothing to do with how you use the fire extinguisher on the bulkhead. But what DOES it mean, exactly?

Naval Ordnance and Gunnery (NavPers 10797A) defines fire control as "The practical application of exterior ballistics, and the methods and devices used to control guns and other weapons. . . ." Another way to put it, in terms of weapons, missiles, and targets, would be to say that fire control is the process of determining the exact relationship between a weapon and its target, and then using that information to get the weapon's missile to strike or inflict maximum damage on that target.

A Little History

When you remember how long it has been since gunpowder and guns first were used in warfare—over six hundred years—it's something of a surprise to realize that fire control as a specialized technique has been with us for relatively so short a time. In fact, the Navy rating of Fire Controlman (now Fire Control Technician) was created AFTER the first World War!

Early guns, projectiles, and propellants were crude and ineffective—so much so that military men could argue with considerable truth that the crossbow and the long bow were more efficient weapons than early hand guns. (After all, a crossbow's arrow could penetrate a knight's armor, whereas the early small-arms bullet could not.) When gunpowder was a novelty, the effect of gunfire was chiefly psychological: the smoke, flash, and noise of primitive firearms could scare the enemy's men. But as the novelty wore off, they could barely scare even the enemy's horses.

Fire control at sea was just as crude, and it stayed that way for a long time, because of the unreliable ammunition and the irregular, handmade equipment of the early days. It wasn't altogether lack of proper instruments that delayed the development of fire control. Manufacturing methods were incredibly primitive. Accuracy to the ten-thousandth of an inch is commonplace today, but 300 years ago a gun bore five feet long was considered excellent if it was no more than half an inch out of true. Even as late as the end of the eighteenth century, James Watt's famous steam engine was considered a remarkable engineering achievement because the cylinder fitted the piston so closely that a shilling (a coin about the thickness of a quarter) couldn't be pushed between them at any point!

With equipment as crude as this, with projectiles of ballistically unfortunate shapes and sizes, and with the unreliable, sensitive, but weak black powder that was the best that the primitive chemistry of the day could produce, something more than improved fire-control equipment was needed. Even if Christopher Columbus had had the Mk 56 director, and his crew had known how to use it, his gunnery would still have been worth little beyond 80 yards or so.

For over four hundred years there was no substantial improvement in ordnance equipment or gunnery techniques. It's been said that a naval gunner of Columbus' days, if he could have been reincarnated in Nelson's time three hundred years later, would have had to learn practically nothing new to help man a gun at Trafalgar. Gunnery required physical bravery, endurance, and a strong back; its greatest subtleties were in knowing such tricks as firing your cannon at the top of your ship's roll, so that you could sweep the enemy's rigging as you came broadside, or firing at the bottom of the roll to blast his hull.

And effective naval gunnery was limited to point-blank ranges. It is true that in some accounts of early naval engagements (such as the battle between the USS *United States* and HMS *Macedonian* in 1812), you'll read of effective fire being opened at ranges up to a mile or two. Such shots, however, involved not only much expert gunnery but also a great deal of luck. Toe-to-toe slugging, ramming, and boarding were the decisive stages of the naval battle before 1870.

All at once, during the nineteenth century, as the Industrial Revolution picked up speed, ordnance began to turn into precision machinery, and gunnery began to evolve from a sort of art of individual marksmanship into the scientific technique of fire control that we know today. After the Civil War, breech-loading guns entirely supplanted the muzzle loaders, elongated projectiles and rifled gun bores became the rule, and scientific analysis of powder composition and burning characteristics made possible the development of dependable, uniform propellants.

One of the Navy's most important steps in the early development of the scientific techniques of fire control was to establish the first Naval Proving Ground at Annapolis, Md., in 1872. (The present one is at Dahlgren, Va.) Here began the process, still under way today, of developing standardized ammunition and range tables, which made possible the accurate prediction of projectile flight, and hence the effective utilization of precision fire-control instruments.

Toward the end of the 1890's LT Bradley A. Fiske, USN, developed a telescope sight that compensated not only for range but for speed of target and drift.

From 1900 to 1910 fire control developed more than it had in the previous 400 years. In rapid succession appeared the coincidence rangefinder, the rate of change of range projector, range clocks, and plotting and tracking boards.

Around 1913 the various fire-control instruments for the main battery began to be consolidated into one box called the **DIRECTOR.** A little later came the earliest **RANGEKEEPER,** predecessor of today's rangekeepers and computers. In fact, the surface fire-control problem was pretty well in hand by the outbreak of World War I.

The second great phase of fire-control development—antiaircraft fire control—began during the first World War. But the first AA director (for the old 5"/25 battery) did not appear until 1926. It was around this time, too, that the Fire Controlman first put in his appearance.

You can get a pretty good idea of the tremendous development of fire control by comparing the ranges between ships in historic naval engagements early and recent. (We are considering gunnery duels here, not aircraft attacks.)

Typical of Lord Nelson's tactics at Trafalgar and the naval tactics of the preceding 200 to 300 years was exchange of gunfire at 20 to 80 yards. Even as late as the Civil War, the engagement between the *Monitor* and the *Merrimac* took place almost entirely at approximately 100-yard range. (Even at this close range, the gunfire of the two vessels did relatively little serious damage.)

In the decisive naval battle of Tsushima during the Russo-Japanese War (1905) the range varied from 4,000 to 6,000 yards. In ten years the range nearly quadrupled. At the Dogger Bank naval engagement early in World War I, the opening range was 18,000 to 20,000 yards. By the end of World War I improvements in fire-control instruments had made 24,000-yard ranges practicable.

By the end of World War II developments in gun construction and in ranging and computing instruments raised range limits to 40,000 yards. Other fire-control instruments used in conjunction with radar made it possible to sink distant enemy ships at night without even sighting them.

Modern Fire-Control

Today, fire-control instruments used in conjunction with guns are limited in range and accuracy only by the inherent accuracy possible with projectiles fired from guns. And the whole scope of fire control itself, as a technique for guiding instruments of destruction so that they will do the maximum damage to the enemy, has been broadened. Where fire control once meant only control of gunfire, it now applies to control of guided missiles, rockets, and weapons directed against underwater targets.

Later in this book, we'll briefly take up fire control in these broader aspects. But in this chapter we shall go a little deeper into the phase of fire control of chief interest to you as a Gunner's Mate—the GUN FIRE-CONTROL PROBLEM.

WHY FIRE-CONTROL IS IMPORTANT TO YOU

This is a good time to answer the question that has probably occurred to you: "Why am I, as a Gunner's Mate, concerned with fire control?" There are two important answers to this.

One is that the field covered by the rating primarily concerned with fire control has been expanding so rapidly, especially since the second World War, that some parts of it have become the responsibilities of other ratings. That's why, for example, the Sonarman now operates and maintains some of the gear that used to be identified with the Fire Controlman. Similarly, the Gunner's Mate is responsible for a good deal that used to be in the Fire Controlman's bailiwick—power drives, indicator-regulators, some aspects of battery alignment, and the like. The empire of the Fire Controlman (now the Fire Control Technician) has changed too—it includes electronics, optics, mechanical computing equipment, and other subject matter not originally identified with it. So that now you, as a Gunner's Mate, are expected to learn more about fire control—and about hydraulics and electricity—not because you're being remolded into Fire Controlmen, but because these, among others, are now the Gunner's Mate's business.

The second answer has to do with the fact that as a Gunner's Mate you must be able to qualify as a mount captain. This means you must be proficient enough in fire control techniques and basic knowledge to supervise your mount's functioning in local control.

There's a third answer too, and it has to do with your own future. You want to earn a Gunner's warrant eventually. To qualify, you'll have to know your fire control.

WHAT'S THE PROBLEM?

The objective of any gun fire-control system or technique is to aim or lay the gun or battery and to fire the projectile so that the projectile will meet the target.

Put this way, it sounds simple, but as a matter of fact it is far from simple. As other parts of this chapter will bring out, the path of the projectile is not straight. The target may be moving (and usually is, often at high velocity), and maneuvering in evasive action. The ship on which the gun is mounted is pitching and rolling. The projectile doesn't reach the target instantaneously; it takes time to get there, and during this time the target moves too. The condition of the gun, the gas pressure in the gun chamber, the shape of the projectile, all affect the projectile's flight path. Moreover, once the projectile leaves the gun muzzle, there isn't much that anybody can do about steering it, or correcting its flight path. It's no guided missile. The problem, you can see, is difficult.

But "difficult" is not "impossible." The problem has been solved, and, as you saw a few pages ago, the solution is getting more and more accurate all the time. Let's learn a little more about the problem and its solution.

A Simple Demonstration

The lowly soda-acid fire extinguisher is not a "fire-control instrument" in the sense this chapter is concerned with, but it's handier than a real gun would be for demonstrating some of the basic principles of fire control and projectile flight. See figure 6–1.

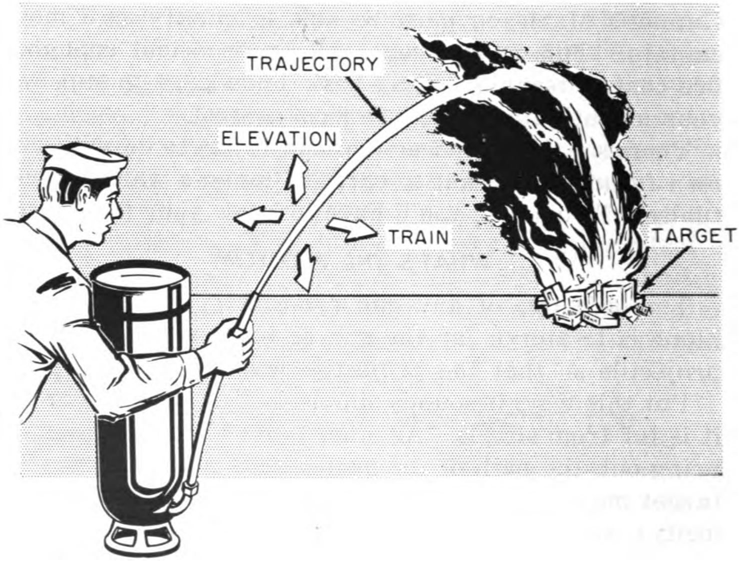


Figure 6–1.—Demonstration of the principles of fire control.

Turn the extinguisher upside down and aim it at its target. First of all, the nozzle is like a gun. You can ELEVATE and DEPRESS it (raise and lower the nozzle), and TRAIN it (swivel it from side to side).

Second, every drop of liquid coming out is a PROJECTILE. There are so many drops that you can see the whole path of projectile movement at once. This is the TRAJECTORY.

Third, the stream of liquid strikes the fire (or whatever you're aiming at)—that's the target.

As you aim the stream at the target, notice that its path (except at very close range) forms a curve. Therefore, you cannot point the nozzle directly at the target, like the beam of a searchlight. Instead, you must aim a little high.

It's the same with a gun. You don't aim the gun at the target. YOU AIM THE GUN IN SUCH A WAY AS TO CAUSE THE PROJECTILE TO HIT THE TARGET.

Getting back to the fire extinguisher, suppose you walk away from the target. You will have to POINT (elevate) the nozzle a little higher, and train it as you move. (You do the same if your target moves away.) Now suppose a strong breeze strikes the stream, deflecting it away from the target. To compensate for this, you must move the nozzle a little further off your target, in order to hit it.

Last, suppose you operate the extinguisher while swaying in a rocking chair. You have to do a good bit of nozzle-waggling to keep the water stream on target. Of course, if you were really trying to direct the stream at a fire, you wouldn't sit in a swaying rocking chair to do it. But the problem is not unlike that of laying a gun aboard a pitching, rolling ship.

The fire extinguisher demonstration has taught us something about the behavior of guns and projectiles. But this is only a beginning. The fire-control problem is concerned with the relationships of the target, the projectile, and the gun that fires it. There are a number of basic concepts for us to learn.

THE TARGET

Let's begin with the target.

The projectile travels a curved path, and takes time to reach the target. To lay the gun right, we must know where the target (whether it's moving or not) will be when the projectile arrives to meet it. To do that, we must know certain things about the target.

The most important thing to know about any target, moving or stationary, is its location. And we must describe its location in terms of the gun which will fire at it. Knowing its latitude and longitude isn't enough. We must have data that can be used to lay the guns. Those data are:

1. The straight-line distance along the LINE OF SIGHT to target in yards (RANGE) (fig. 6–2).
2. The direction of the target in the horizontal plane, reckoned from the bow of the ship (RELATIVE TARGET BEARING; see fig. 6–2), or its true compass bearing (TRUE TARGET BEARING). The angular distance of the target from the reference point (the ship's bow or true north, depending on which kind of target bearing is being used) is measured in degrees (°) and minutes (') of arc (360° to the full circle).
3. For surface targets, Nos. 1 (range) and 2 (target bearing) are enough to describe target location. But in antiaircraft (AA) work, we must know also the vertical angle between the line of sight and the horizontal plane in which the gun is located (TARGET ELEVATION).

All three of these are illustrated in figure 6–2.

The Moving Target

With a stationary target these factors are all you need to know about the target to hit it. Unfortunately, not many targets are stationary. Besides, even when the target is stationary, your ship usually is not. So you must take into account:

4. TARGET AND OWN-SHIP MOTION. Much of the real job of the fire-control system comes in at this point. The surface target may either be approaching or moving away from your ship; its bearing with respect to your ship is also constantly changing. Even if the target is at rest and your ship is moving, the effect is the same, as far as the fire-control system is concerned. With air targets, of course, not only range and bearing change constantly (and fast, in comparison with surface targets) but so does eleva-

tion. What you have is really a problem in prediction—but it's a problem for a computer rather than a crystal ball. The computer figures out where the target is going to be when the projectile gets to it so that the gun can be laid accordingly.

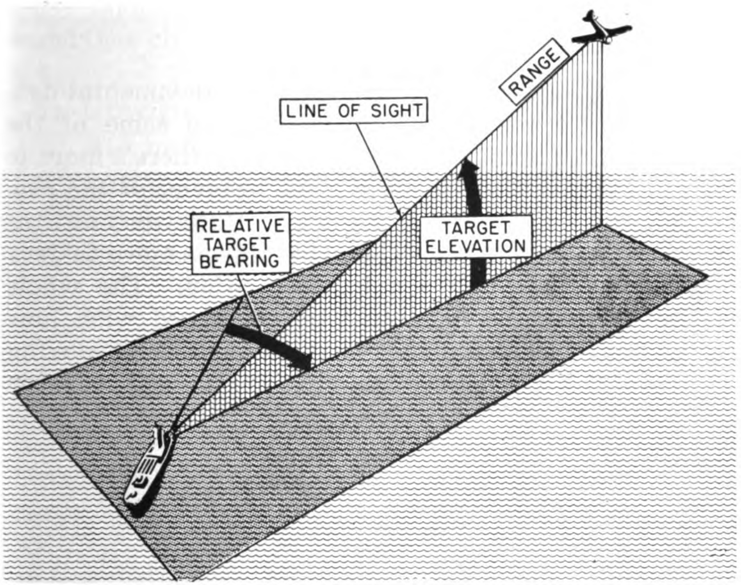


Figure 6—2.—Relative target bearing, range, and target elevation (for an air target).

The problem of the moving target is by no means a Navy monopoly. On a smaller scale, every hunter of every kind of game, every amateur in a shooting gallery—in fact, every one who has tried to hit with any kind of missile any kind of moving target—has had to solve the problem, without a computer. The way to do it is to LEAD the target—to aim at a point, ahead of the target and in its path, which the missile and target will reach at the same time. How much lead to give the target?—that's the problem. The hunter uses his experience and judgment—but he also may use a shotgun to improve his chances of hitting the target even if his estimate of lead isn't perfectly accurate. The Navy's targets generally move a lot faster than the hunter's and they aren't vulnerable to shotgun pellets. Hence the Navy uses a computer to make the estimate as accurate and speedy as possible.

THE PROJECTILE IN FLIGHT

So far we have taken up some of the fundamental definitions in fire control, and have outlined some of the problems concerned with the target. But there's more to fire control than that. Consider the behavior of the projectile after it's sent on its way. However fast the projectile moves (and few manmade objects move faster) it does take time to reach its destination. The whole science of EXTERIOR BALLISTICS is concerned with how the projectile behaves and what happens to it during

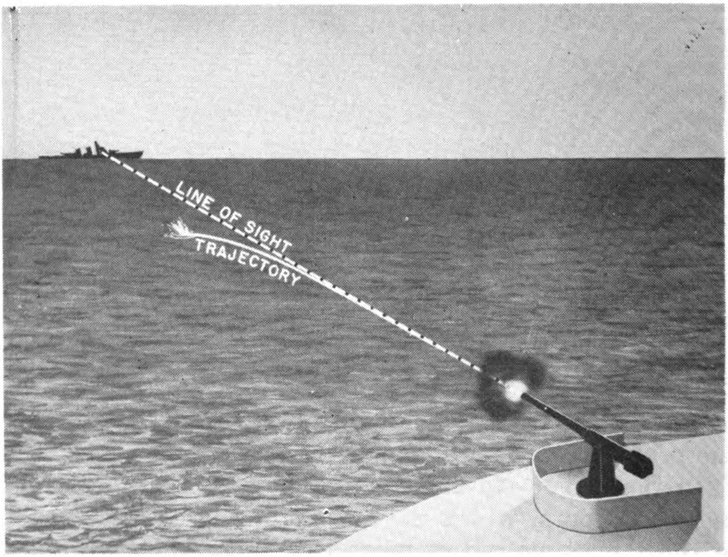


Figure 6–3.—Firing a projectile from a gun cannot keep it from falling.

this very brief period that it's in flight. These things are very important to anybody whose business it is to see that the gun projectiles he fires meet their target.

During flight, a gun projectile is subject to a number of forces which influence its behavior and flight path. Not all are of equal importance. Any fire-control system must take into account those that are most important under the circumstances. The five most important ones are:

1. Gravity
2. Air resistance
3. Drift
4. Wind
5. Earth's rotation and curvature

Gravity

Gravity is the most important of these. Its effect is to curve the trajectory. Out in interstellar space, where space opera fans feel at home, there is little or no gravitational force. If you were out there and fired a projectile, its trajectory would be a straight line. But here on earth, gravity is constantly pulling the projectile downward, regardless of its velocity.

A projectile in flight is always falling. It has no wings and cannot fly, in the sense of being airborne. Firing it from a gun cannot keep it from falling (fig. 6–3). If you were to fire a projectile at 0° elevation (that is, with the gun perfectly horizontal), and at the same time drop a similar projectile over the side from exactly the same height as the gun, both would fall into the sea at exactly the same instant. Of course, the projectile fired from the gun would be quite some distance away when it hit the water, but it would FALL just as fast as the one merely dropped.

Therefore, to keep the projectile in flight until it reaches the target, the gun is TILTED or ELEVATED so that it is directed toward a point ABOVE the target. If the tilt

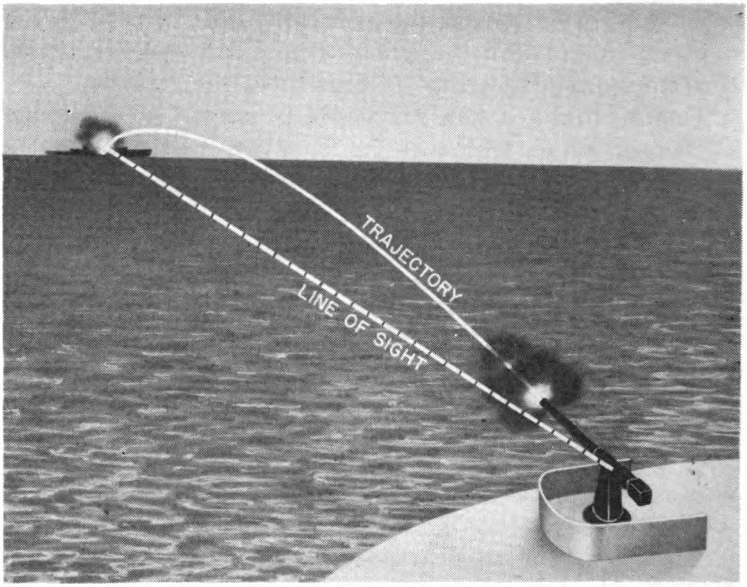


Figure 6–4.—Elevating the gun to increase range.

is right, the trajectory will pass through the target (fig. 6–4).

The greater the angle of gun elevation the greater the range—up to a point. For there are limits as to how far we can get a projectile to travel this way. Temporarily

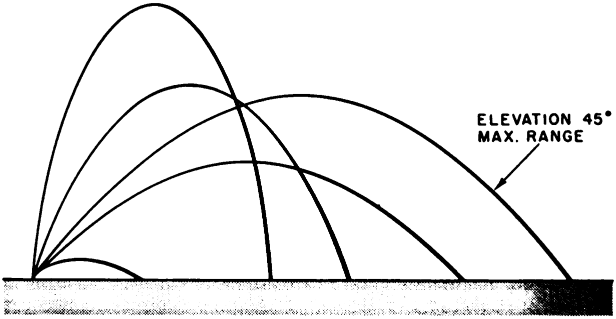


Figure 6–5.—Theoretical trajectories at various gun elevations (neglecting air resistance).

ignoring air resistance, we find that range increases with the angle of elevation, up to 45°. After that point, increasing the elevation increases the height reached by the projectile, but decreases the range (fig. 6–5).

Fire at surface targets using gun elevations of more than 45° is fairly common with land artillery pieces like howitzers and mortars, but these techniques are adapted best to use against targets protected by hills or ridges. They are not important in naval gunnery except in connection with shore bombardment.

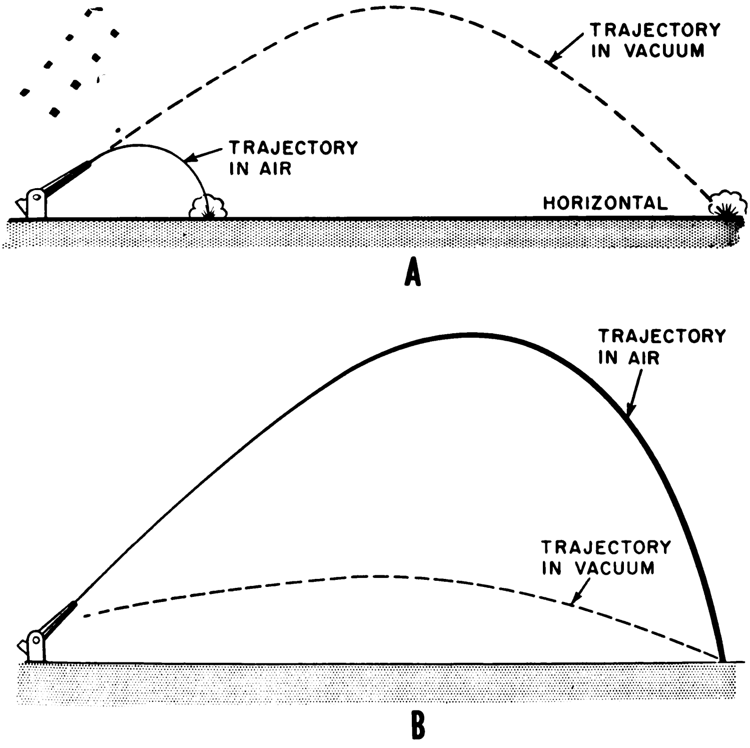


Figure 6–6.—Comparison of vacuum and air trajectories A. In range. B. In gun elevation.

Because, so far as naval gunnery is concerned, the effect of gravitational pull is the same everywhere, you can always depend on it to have a uniform effect on the projectile. Range tables and computers can be depended upon to provide the proper gun elevation for a target no matter where on earth your ship is when it's firing its guns.

Air Resistance

Having dealt with the effect of gravity, we have still other factors to take into account. Consider air resistance.

Even today, many people think of the air in our atmosphere as pretty thin stuff. But anything that can support 50-ton aircraft, and cause meteors to heat up to incandescence as they plummet to earth, can't be considered really thin. So it is with projectiles. Look at figure 6–6. The trajectory in vacuum is only theoretical, because it ignores air resistance. But a projectile speeding along at nearly half a mile a second can't ignore air resistance. It doesn't fly through the air; it PLOWS through. Figure 6–7 shows what a disturbance it causes.

The disturbance the projectile makes slows up its

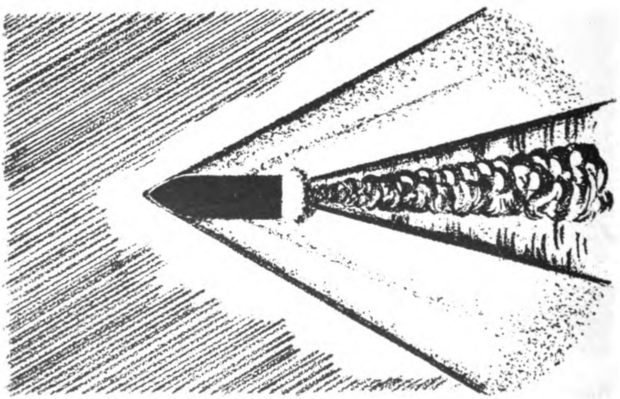


Figure 6–7.—Portrait of a projectile in flight.

flight. This keeps it from going as far and as high as it would in a vacuum (in fire-control language, reduces horizontal and vertical range), and causes it to fall at a steeper angle (fig. 6–6B). If you've played badminton, you've seen an exaggerated example of the same effect. No matter how hard you sock the shuttlecock, the high air resistance of its feathers keeps it from going as high and as far as you expect, and it always falls almost vertically.

The effect of air resistance is much more severe with smaller projectiles. Any projectile fired in a vacuum at an elevation of 40° and an INITIAL VELOCITY (the speed of the projectile as it leaves the gun) of 2,500 feet per second will attain a horizontal range of 192,000 yards (almost 100 miles)–and that means ANY projectile, from a caliber .30 rifle bullet to a 16-inch projectile. But, in air, the 16-inch projectile will go 42,000 yards; the 5-inch, 17,000 yards; and the caliber .30, about 3,500 yards. Figure 6–6A shows how drastically air resistance shortens the trajectory possible in a vacuum.

As with the effects of gravity, the way to compensate at least partially for air resistance is to increase range by additional gun elevation. In figure 6–6B, the dotted line shows the trajectory of a projectile in a vacuum. Notice how much additional elevation the gun must have to fire the projectile the same range through air (solid line trajectory).

Air density is not a constant like gravity. It varies with altitude and barometric pressure. The amount of compensation necessary, therefore, depends not only on range, but on how high the projectile will go and on weather conditions at the time of firing.

Wind

In discussing air resistance, we assumed for simplicity's sake that the air didn't move, because the effects of air density on projectile flight exist whether the air is moving or not. But the air does move, and the movement is WIND—the third factor in shaping a projectile's trajectory.

Fire control theoreticians define everything with great precision, and even so everyday a phenomenon as wind is no exception. Wind is not only movement, but movement with respect to something. If it's with respect to something "stationary"—the earth—it's TRUE WIND.

But you're on a moving ship. Even if there is a dead calm, you feel air movement. That's wind, too, as far as gunnery is concerned. Your ship may be moving north, the true wind may be coming from the west, and you feel a northwest wind. That kind of wind, including both air movement and ship movement, is APPARENT WIND.

The effect of wind on projectile flight depends on how much the wind blows across the line of fire (CROSS WIND), and how much it blows along the line of fire (RANGE WIND). The effect of range wind is obvious. It tends either to push the projectile along, or to blow against it and retard it. Similarly, cross wind pushes the projectile either to the right or left, deflecting its path.

Cross wind causes another effect, too complicated to explain fully here, but it works like this: Because the projectile is spinning clockwise at high speed as it leaves the gun, a cross wind from left to right, besides pushing the projectile sideways, DECREASES RANGE, while a cross wind from right to left INCREASES RANGE.

When real accuracy is wanted, balloons are sent aloft and observed, so that the wind at various altitudes can be measured. When all winds are taken into account, they are combined mathematically into one wind direction and speed which would have the same total effect. This is the BALLISTIC WIND which is introduced into the fire-control computations.

Drift

The fourth factor that affects the trajectory of a projectile is DRIFT.

Drift is not a simple effect; it's the product of the interaction of three other factors—namely, the clockwise spin of the projectile, the force of gravity, and air resistance. As the spinning projectile moves through the air, it tends to point slightly above the trajectory, and the air pressure on its underside develops a thrust that tends to tumble the projectile end over end. But like any other rapidly spinning mass, the projectile reacts to a thrust tending to displace its axis of spin by PRECESSING gyroscopically. (You'll learn more about gyroscopic action as you learn more about fire control, so we won't go into detail about it at this point.) In this case, the precessing movement is a slow turn to the right. The result is that the projectile's course is deflected to the right (fig. 6–8) —relatively slowly at first, but more and more as the trajectory lengthens.

The direction of drift depends entirely on the direction of rotation of the projectile. Every rifled weapon in the Navy (with one exception) causes projectile spin to the right (that is, clockwise as viewed from the projectile base), and drift to the right. The exception is the caliber

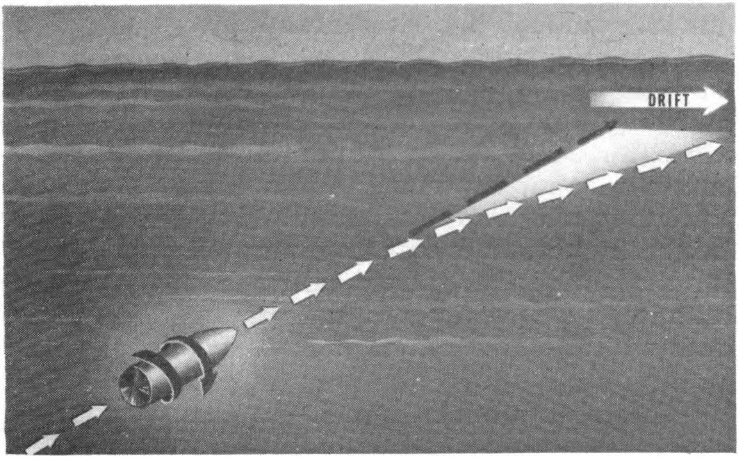


Figure 6–8.—Clockwise projectile spin causes drift to the right.

.45 pistol. Drift increases with range, but is completely independent of wind.

Because of drift, wind, own-ship and target movements, and so on, you will seldom be able to train your gun directly on the target, except at point-blank range. Just as you must elevate your gun to compensate for trajectory curvature in the vertical plane, you must aim your gun laterally off the line of sight to target to compensate for the trajectory curvature these factors cause in the horizontal plane.

Earth's Rotation and Curvature

The fifth of the factors that distort the trajectory of a projectile is EARTH'S ROTATION AND CURVATURE. (These are actually two independent factors, but we lump them as one for convenience.)

So far we have assumed that the earth stands still and is flat. But actually, its movement has an effect on projectile trajectories, while its curvature has an effect on range. The effect of rotation varies with the latitude the gun is in, its bearing, and the range. Both effects only begin to be important in surface fire at extreme ranges—30,000 yards or more.

By far the majority of the guns in our Navy are designed to deal with targets at much shorter ranges than this. At such ranges, although these factors do apply, their effect is so slight that it's hardly worth while to correct for them. Besides, against air targets it's important to solve the important factors of the fire-control problem speedily as well as accurately, and taking minor factors into account is an unnecessary refinement. You'll therefore find that only in controlling the fire of the main batteries of battleships and cruisers are these factors made part of the fire control problem and its solution.

How Corrections Are Applied for These Factors

If projectiles took no time at all to travel from gun to target, and if gravity, air resistance, and the other factors we have just discussed didn't have their irritating way of distorting the projectile's trajectory from the perfectly straight line that it could theoretically be, fire control would be no more of a problem to the gunner than it is to the operator of the space opera's death ray or atomic disintegration beam. However, these factors and their disturbing effects do unfortunately exist—but so do solutions to the problem they create.

We compensate for the effects of these factors by offsetting the axis of the gun bore from the line of sight, so that the gun axis is at an angle to the line of sight. Or, to be more exact, we measure the offset in terms of TWO angles, one in the vertical plane, the other in the horizontal.

To determine the values of these two angles, we add the angular corrections required to compensate for all of the factors we have discussed. For example, the effects of gravity and air resistance can be compensated for at a given range by elevating the gun (angular correction in the vertical plane) by an amount that can be calculated. We compensate for drift by deflecting the gun (angular correction in the horizontal plane) to the left (because drift is to the right)—again by an amount that can be calculated for a given range. To correct for wind, we must first find out the direction and velocity of the wind; the correction in terms of gun deflection and elevation can then be calculated. To lead the target by the proper amount, we must know the target's range, bearing, and rate of movement in terms of rate of change of range and bearing; the proper lead in terms of gun elevation, deflection, and rate of change of these can then be worked out.

Add all these, and the sum gives us the angles which must be added to those that describe the line of sight (namely, target bearing and target elevation, as illustrated in fig. 6–2) to give us the gun position or GUN ORDER that represents correct aim. If the data are correct, and the gun is properly positioned, the projectile is theoretically sure to hit the target.

The mass of calculation implied by the preceding paragraph as being necessary for each shot looks monumentally impracticable. And it's true that it would be, if we had to start from scratch for each shot. But we don't have to start from scratch. The calculations are performed in advance, and the proper ones are merely applied to the problem as required. But how?

When a new gun is designed and built, it's shipped to the Naval Proving Ground in Dahlgren, Virginia, set up on a special stand, and test fired with the ammunition that's designed to be used with it. The velocity of the projectile, the range attained, the amount of drift, and other factors are carefully measured at a number of exactly known gun elevations. From these data, and other data calculated on their basis, range tables are made up that show for each kind of round exactly what the projectile will do at any elevation at which the gun is designed to be fired.

This is done for all naval guns, and such tables can

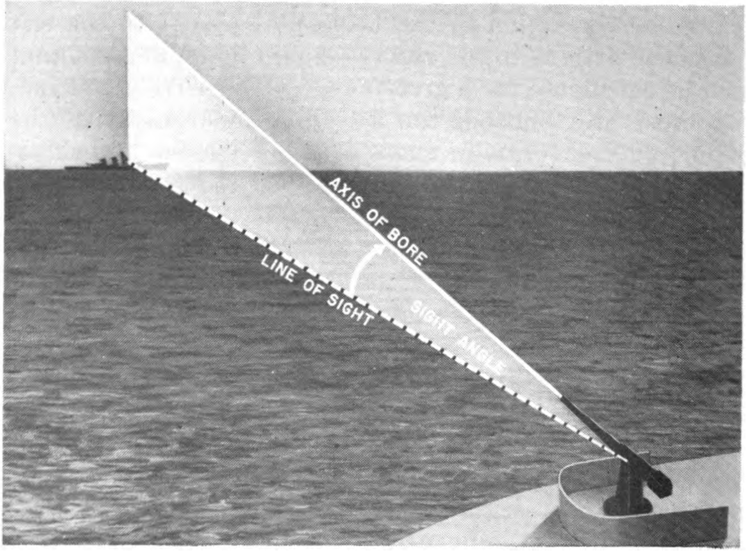


Figure 6–9.—Sight angle.

actually be used for determining the exact angles of offset from the line of sight. In the early 1900's, in fact, they were so used. But even this shortcut is too slow for today's war of movement. Range tables are no longer used in combat, though fire-control problems can be worked out on them as a matter of training.

There is another way to perform fire-control calculations in advance, and that is to have them done by electronic or electrical-mechanical computing devices, which not only work out solutions, but actually control power drives so that the computing devices determine the aim of the gun. This is the way fire control is normally handled in the modern Navy. As a Gunner's Mate, you will not be much concerned with exactly how these devices work, though you will study how the electrical signals which represent their solutions to the fire-control problem are utilized to position gun mounts.

SIGHT ANGLE AND SUPERELEVATION

The angle by which a gun is elevated above the line of sight to a surface target so that the projectile's trajectory will pass through the target is called SIGHT ANGLE. (See fig. 6–9). The angle is measured in minutes between

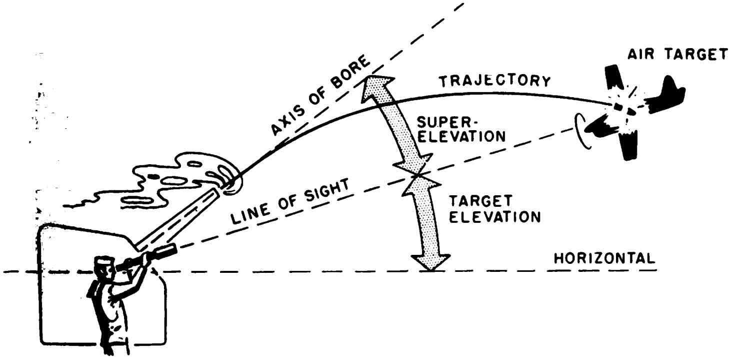


Figure 6–10.—Target elevation and superelevation.

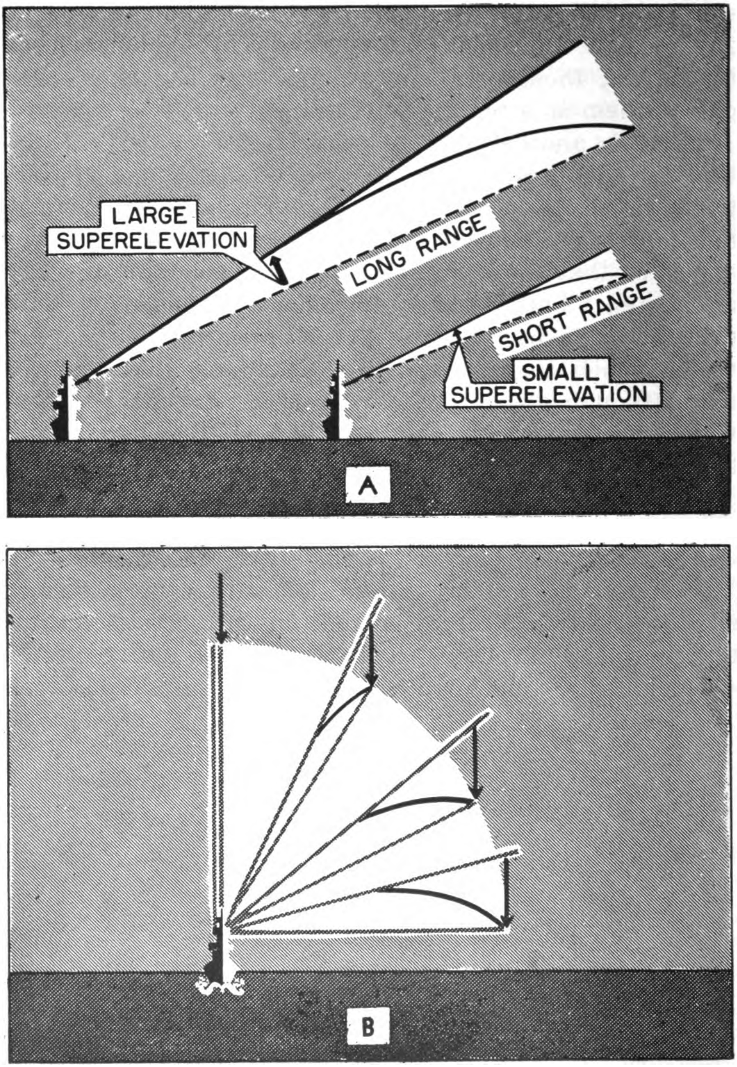


Figure 6–11.—Effect on superelevation of: A. Increased range, B. increased target elevation.

the axis of the gun bore and the line of sight. As range increases, so does the amount of sight angle necessary.

When the line of sight is to an air target, the principle of sight angle still applies, but the name is changed. The line of sight must itself be elevated so that it will meet the target; you will recognize this as TARGET ELEVATION (fig. 6–2). But because the trajectory is curved, we must elevate the gun still further to correct for range. This additional elevation is SUPERELEVATION (fig. 6–10).

As with sight angle, increased superelevation is needed for increased range (fig. 6–11A). But as target elevation increases, superelevation DECREASES (fig. 6–11B).

If you think about it, this is common sense. Consider an extreme case—a target directly above you.

Neglecting all other factors but gravity, it is obvious that a gun fired at such a target would have to be aimed directly along the line of sight at it. Gravity would still pull downward at the projectile, but its pull would be directly in line with the trajectory, which would therefore be straight. Hence no superelevation needs to be introduced. As the line of sight is moved away from the straight-up direction, the downward force of gravity is exerted at an increasing angle to the axis of the gun bore, and therefore has more effect on the shape of the trajectory. This is exactly what figure 6–11 shows.

SIGHT DEFLECTION

Because the trajectory is curved in the horizontal plane as well as in the vertical, the gun must be offset from the line of sight horizontally too. We call the angle of offset SIGHT DEFLECTION, regardless of whether the target is on the surface or in the air (fig. 6–12). Unlike sight angle or superelevation, which is added ABOVE the line of sight in practically every possible case, sight deflection may be either left or right. (In fig. 6–12 it is right.) In addition to wind and drift correction, deflection includes most or all of the lead taken on a moving target—unless the target is moving more up or down than laterally.

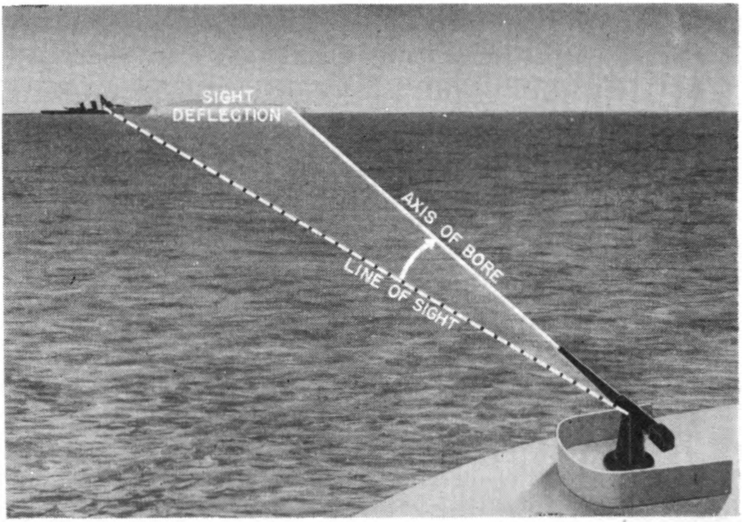


Figure 6–12.—Sight deflection.

Unlike sight angle, target elevation, superelevation, and target bearing, deflection is measured in MILS, not minutes. A mil is, like a degree or minute, a unit of angular measure. It takes about 6,400 mils to make a circle (as compared with 360° to a circle). To be exact, the mil in U. S. naval gunnery is equal to 3.438 minutes of arc, or less than 0.06°. (By the way, don't confuse the ANGULAR mil with the CIRCULAR mil used for measuring electrical conductors.)

The mil has a very useful property. If a distant object appears to you to be exactly one mil wide, then its real width is exactly 1/1,000th of the range. (See fig. 6–13A.) For example, suppose you see a buoy 1,000 yards distant. You sight at it through a telescope in whose RETICLE (a glass plate in the telescope optical system) are lines one mil apart. With the scope, you see that the buoy is just one mil, or 1/1,000th of the range, wide. And since you know that 1/1,000th of the range is one yard, that's how wide the buoy is. Figure 6–13B shows other examples of the mil's usefulness in estimating lateral distances at known ranges.

INITIAL VELOCITY AND OWN-SHIP FACTORS

So far we've concentrated on the characteristics of projectile flight and target activity as they effect fire control. But a projectile's course depends on its start. Nothing can be done about its behavior once it leaves the muzzle of the gun.

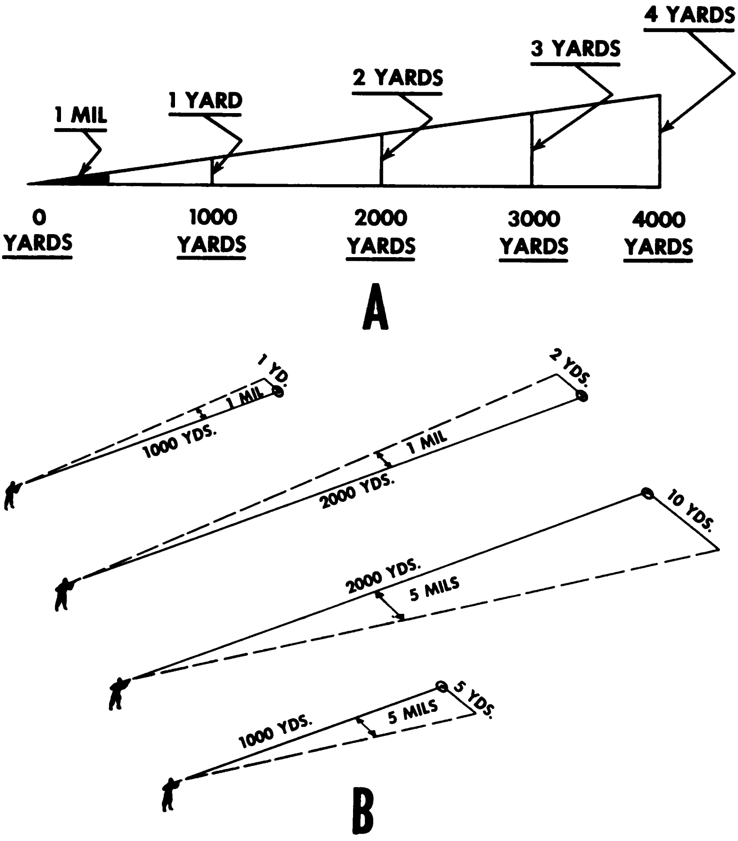


Figure 6–13.—The mil. A. What it is. B. How to use it.

The important things about a projectile's start are how fast it goes (INITIAL VELOCITY or I.V.) and in what direction. A reduced I.V. reduces range; the effect of a start in the wrong direction should be obvious.

Initial Velocity

With a given propelling charge, the chief influences on a projectile's initial velocity are:

1. How worn the gun bore is (EROSION).
2. Variations in the temperature of the PROPELLING CHARGE of the ammunition.
3. Variations in the actual weight of the projectile.

Erosion causes the gun bore to enlarge, and cuts down initial velocity, range, and accuracy of fire.

Lowering the temperature of the propelling charge reduces initial velocity and range. Standard initial velocity, as determined at proving grounds, is based on a powder (propelling charge) temperature of 90° Fahrenheit, the temperature you would expect on a very hot day. (Higher temperatures increase initial velocity and range.)

Variations in projectile weight are not nearly so important in determining I.V. as the other two factors. Projectile weight is not adjusted aboard ship, but the weight is kept within close tolerances at the time of manufacture. so that the slight variations that do exist will not have any serious effect.

Own-Ship Factors

The problem of starting the projectile in the right direction is complicated by factors introduced by your own ship. You can calculate accurate corrections for the target and trajectory, and determine just how the gun must be laid, but the ship itself introduces three important factors that make gun laying on shipboard difficult:

1. OWN-SHIP COURSE AND SPEED affect target motion with respect to the ship. Example: your ship is steaming westward at 10 knots past a stationary target. The effect, so far as fire control goes, is the

same as if the target were moving eastward at 10 knots.

2. The ship ROLLS from side to side, and PITCHES fore and aft. This tilts the gun mount, causing errors in elevation and train.
3. The circular steel ROLLER PATHS on which turrets and gun mounts revolve are not exactly parallel to each other or to the plane of the deck.

Take No. 1 first. For fire control, own-ship course and speed are considered as they effect apparent target motion—that is, they are added algebraically to target motion, and gun laying is corrected accordingly.

Next, No. 2: Nobody yet has designed a warship that is completely immune to roll and pitch. As far as gunnery is concerned, nobody needs to, because there are other ways of solving the problem. One is to use a gimbal-mounted gyroscopic mechanism called a STABLE ELEMENT or STABLE VERTICAL, which itself maintains complete stability. These devices introduce corrections which cause the gun mount and turret power drives to move the guns continuously so that they are continuously laid in the right position for hits. Or the same gyroscopic device may operate the firing circuit so that the guns pitch and roll with the ship, but can fire only during the instant when they happen to be in the position that corresponds to being properly laid for a hit on the target.

Another solution (used as an alternative to these if the stable element or stable vertical is out of action) is to have telescopes in the battery director aimed continuously on the horizon as the ship pitches and rolls. Signal transmitters coupled to the telescopes generate electrical correction signals which can be used like those from the stable element or stable vertical.

Now for No. 3—inclination or tilt of the mount roller path. The difficulty is unavoidable. When a ship is on the ways or in drydock, it is supported quite differently from the way in which the water supports it when afloat. This causes a certain amount of flexing or bending of the structure. Even though warships are designed and built to be much more rigid than commercial craft, they suffer for this reason slight realignments of structure when afloat, as compared to when they are in drydock. That is why a gun mount's roller path, though as close to parallel with the plane of the ship's deck as engineering can make it when the ship is in drydock under construction, may be tilted as much as 1° off when the ship is afloat, fully armed and manned, and ready for action. (One degree may not seem like much, but in a 16" turret, for example, a 1° error in gun elevation can mean an error of 1,200 yards in range.)

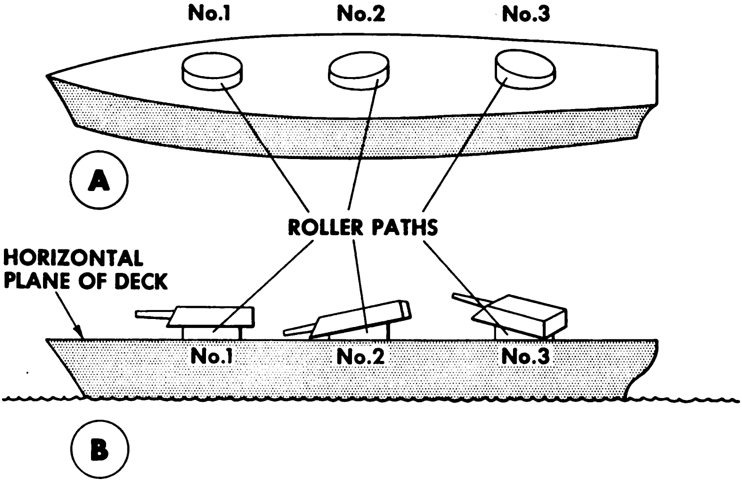


Figure 6–14.—Roller path inclination.

Figure 6–14 shows the effect of this (much exaggerated). Each of the three gun mounts in the diagram is nominally at zero elevation, and should be parallel to the horizontal plane of the deck. But only No. 1 is really at zero. Nos. 2 and 3 are tilted, and the amount of tilt will vary as the mounts train to different bearings.

In this course we cannot go into detail on this (it's taken up in a later one in this series), but the problem is solved by first measuring with great precision the exact tilt of the roller path with respect to some reference plane (usually the battery director roller path), and then adjusting a ROLLER PATH COMPENSATOR installed in the gun mount. (Each mount has one.) This device automatically causes the gun to elevate or depress just enough to compensate for the tilt of the roller path at every point to which it is trained. Checking and (if necessary) resetting the compensator is part of the battery alignment procedure.

SUMMARY

In this chapter we have studied the background and function of fire control, and the factors which introduce complications into the process of laying a gun so that its projectile will hit the target, taking up in turn those that concern the target, the projectile, and the gun.

In the next chapter we shall take up fire-control systems—their elements, how they are organized, and how they are used—as well as spotting techniques and communications systems.

QUIZ

In the following multiple-choice questions, select the one BEST answer.

1. The trajectory is
   a. the straight-line distance from gun to target
   b. the angle at which the gun must be pointed in order to make the projectile strike the target
   c. the distance that the gun must be pointed ahead of moving target to ensure a hit
   d. the path of projectile movement from the instant it leaves the muzzle of the gun

2. True target bearing is
   a. the true rate of change of target bearing as it moves across the line of sight
   b. the direction of the target from the ship as reckoned from true north
   c. the bearing on which the gun must be laid to ensure hits
   d. the true compass direction in which a moving target is heading at the time the gun is fired

3. The vertical angle between the line of sight and the horizontal plane in which the gun sight is located is called
   a. target elevation
   b. sight angle
   c. superelevation
   d. slant range

4. At which of the following points in its path is the projectile LEAST subject to the force of gravity?
   a. When it is traveling fastest
   b. When it is spinning at its highest rate
   c. While it is rising in its path
   d. None of the above

5. Air resistance not only shortens the path of a projectile, but also
   a. heats it to incandescence
   b. causes it to be more subject to the force of gravity
   c. causes it to fall at a steeper angle
   d. tends to keep it pointed in the direction of the target

6. True wind velocity and direction are measured with respect to
   a. the earth
   b. apparent wind
   c. velocity and direction of ship movement
   d. the sum of range wind, cross wind, and ballistic wind

7. Which of the following is NOT one of the three interacting forces that produce projectile drift?
   a. Projectile spin
   b. Gravity
   c. Wind
   d. Air resistance
8. In laying a gun to fire at an air target, the total gun elevation is the sum of
   a. deflection and target elevation
   b. target bearing and target elevation
   c. target elevation and superelevation
   d. sight angle and superelevation
9. Superelevation decreases as
   a. sight angle increases
   b. target elevation increases
   c. range increases
   d. deflection decreases
10. Which of the following is measured in mils?
    a. Superelevation
    b. True bearing
    c. Sight angle
    d. Sight deflection
11. One way in which the stable element and stable vertical correct for roll and pitch is by producing correction signals which
    a. control the mount power drives
    b. control the ship's gyrostabilizer
    c. prevent functioning of the gun firing mechanisms unless the ship is completely stable
    d. drive telescopes in the gun mount so that they sight continuously on the horizon.
12. The function of the roller path compensator is to
    a. adjust roller path tilt to compensate for true gun elevation
    b. cause the gun to elevate or depress to correct for roller path tilt
    c. cause the gun to remain at zero elevation at any angle of train.
    d. adjust angle of train to compensate for direction and elevation of roller path tilt

CHAPTER 7

FIRE-CONTROL SYSTEMS AND TECHNIQUES

INTRODUCTION

In the preceding chapter, you learned about the fundamentals of fire control as applied to gunnery. In this chapter, we shall take up fire-control equipment (especially the gear you find on gun mounts), the remote control system, fire-control communications, and spotting.

FIRE CONTROL AT THE GUN MOUNT

In the preceding chapter we took up what you must know about the location and movement of the target in order to aim or lay a gun so that its projectile will hit the target. We also learned about various factors that distort the trajectory of the projectile, and that therefore the gun must be laid so that the axis of its bore is offset from the line of sight to the target.

In this section we'll take up the equipment located at the gun mount that enables the gun to be laid accurately for hits. For the moment, we'll discuss the gun mount and its fire-control problems as an independent unit. Later we'll discuss how it fits into the central fire-control systems that control the aiming and firing of all guns on the ship larger than 20-mm. Bear in mind that the normal or PRIMARY method of fire control, called AUTOMATIC or REMOTE control, is through the ship's central system. Independent control of the mount by its crew, called LOCAL control, can be used by all naval gun mounts and turrets, but only as a SECONDARY method. For reasons that will be discussed later, local control cannot be as accurate or as well coordinated as automatic or remote control.

SIGHTS

The device that is mainly responsible for applying corrections to the line of sight so that the gun can be properly aimed is the SIGHT.

This is a relatively new development in gunnery. Before the early 1800's, no self-respecting gunner felt that he needed to use sights, particularly at the modest ranges then possible. The earliest sights were vertical pointed bars, one secured to the breech and one to the muzzle, adjusted so that the line of sight (LOS) across their tips was parallel to the gun's bore. Then in 1845 a French army colonel had the bright idea of moving the rear sight up and down on a vertical metal slide or leaf, so that the LOS could be tilted with respect to the gun bore. Or, in other words, he could vary the sight angle and so adjust for range. The modern rifle or machine gun leaf sight works just this way today (fig. 7–1).

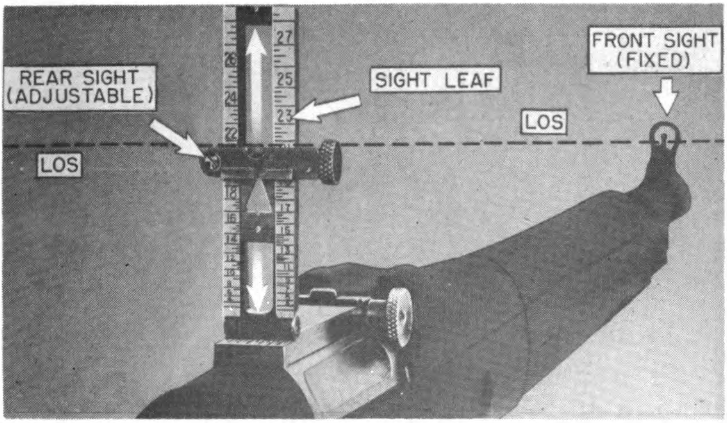


Figure 7–1.—Leaf sight, U.S. Army rifle, M1903.

As guns improved in range and accuracy, they became capable of firing at ranges so great that the naked human eye looking through a simple sight could no longer direct them effectively. The obvious answer was to use telescopes. By the end of the Spanish-American War our Navy had telescopic sights that could compensate for drift as well as for range.

Peep and Ring Sight

The simplest sight used in present-day naval gunnery is the PEEP AND RING SIGHT, which you'll find as an auxiliary or secondary sight on open AA and dual-purpose gun mounts (fig. 7–2).

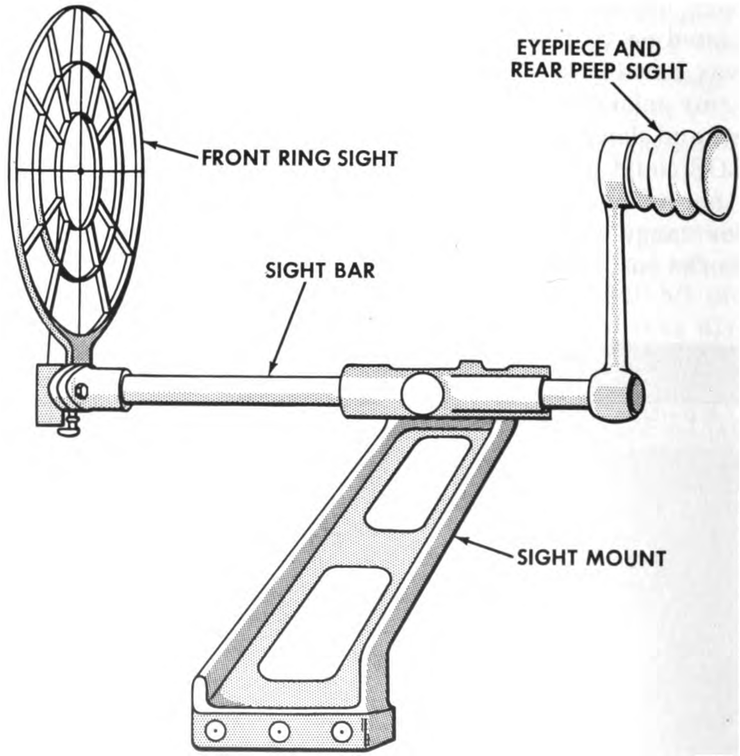


Figure 7–2.—Peep and ring sight.

There are no moving parts in this sight with which to shift the LOS. Instead, the pointer or trainer using the sight shifts his eye to align it with the proper section of the front ring, thus shifting the line of sight as required. Because of its simplicity, this type of sight is especially valuable against close-range high-speed targets, like aircraft.

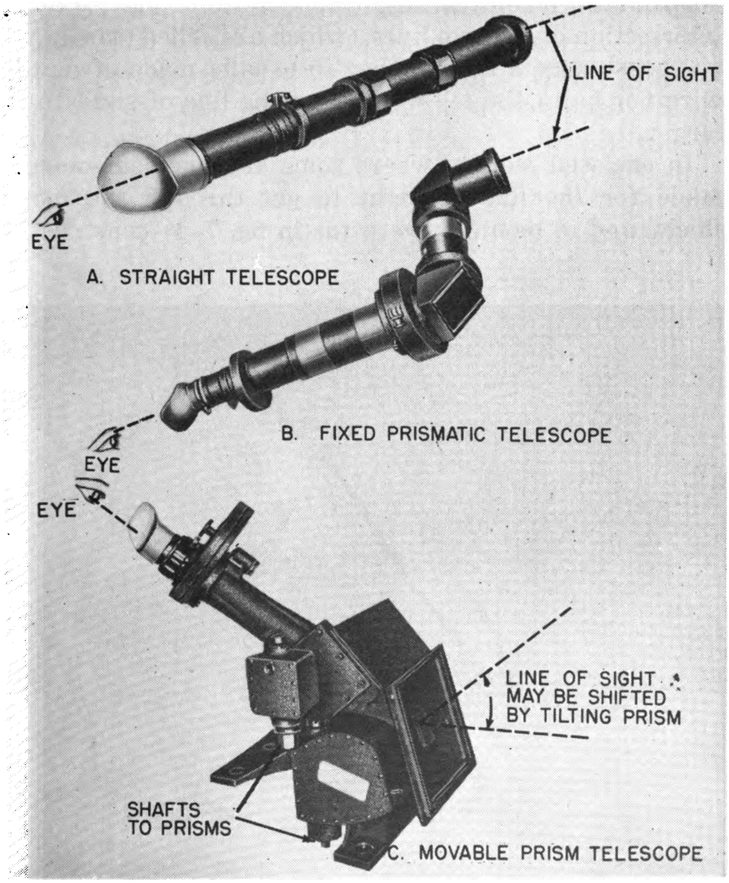

LINE OF SIGHT
EYE
A. STRAIGHT TELESCOPE
B. FIXED PRISMATIC TELESCOPE
EYE
EYE
LINE OF SIGHT MAY BE SHIFTED BY TILTING PRISM
SHAFTS TO PRISMS
C. MOVABLE PRISM TELESCOPE

Figure 7–3.—Three types of sight telescopes.

Sight Telescopes

For longer ranges the eye needs optical aid, which means a telescope. Figure 7–3 shows several types now in use in naval armament. The optical system of the straight telescope (A in fig. 7–3) is quite similar to that of a conventional terrestrial telescope, except that it includes a RETICLE—a glass plate on which is etched a pattern of two lines at right angles, one vertical and one horizontal. When the target appears to be located at the intersection of the two lines (which are called CROSSHAIRS or CROSSWIRES, although they're usually made of neither wire nor hair) the telescope is on the line of sight to the target.

In enclosed mounts where some arrangement must be made for the line of sight to get through the mount shield, and in mounts where (as in fig. 7–4) construction

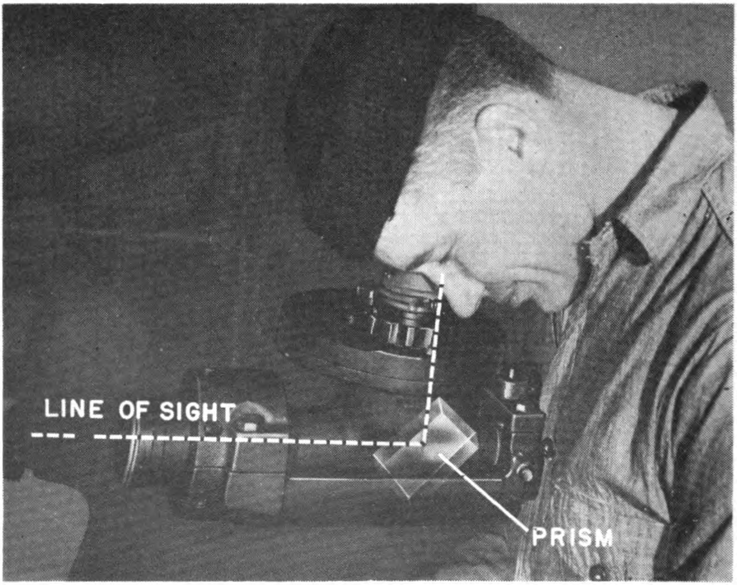


Figure 7–4.—How the line of sight is bent in a prismatic telescope.

doesn't permit location of telescopes where the pointer and trainer can use the straight type conveniently at all elevations, you find PRISMATIC telescopes. A prism can reflect light or "bend" the line of sight (fig. 7–4) as required without losing accuracy. Figure 7–3B illustrates a telescope with two prisms, for use where armor prevents installation of a straight telescope.

Sights may be installed on a gun slide so that they train with the mount and elevate or depress with the gun. Such SLIDE-MOUNTED sights are found on gun mounts smaller than 5-inch. But in mounts 5-inch and larger, the sights are CARRIAGE-mounted; they train with the gun, but as part of the mount structure they cannot elevate and depress with it. (Figure 7–5.) A way to

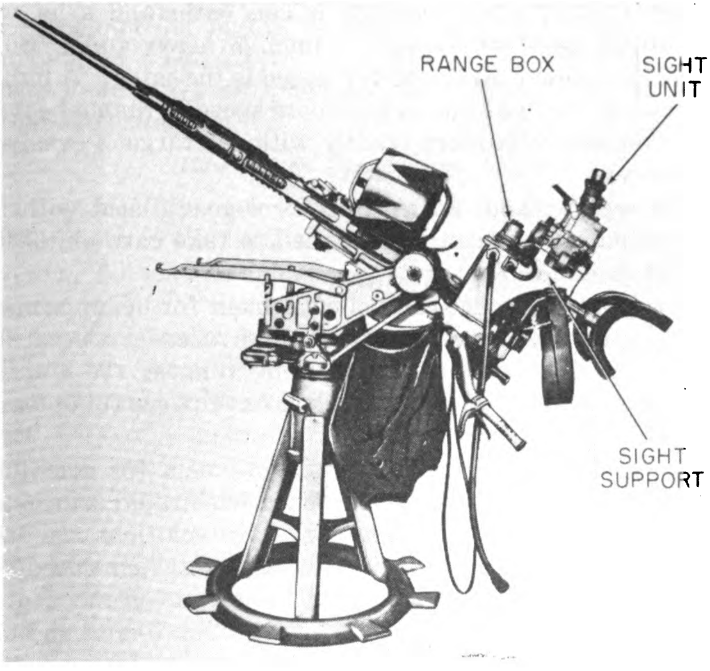


Figure 7–5.—Gun sight Mk 20 Mod 5 mounted on a 20-mm gun.

solve this problem is to move some of the optical parts of the sight to shift the line of sight in deflection and elevation, without moving structural parts. In 5-inch mounts, this is done by moving prisms (fig. 7–3C). The shafts to the prisms are operated by the gun elevating gear.

Sights and Ranges

As you know, the caliber of a naval gun is related to the range at which it is designed to be most useful. The big ones are used against targets a dozen miles or more away; the light machine gun batteries come into their own when the target gets within some 2,500 yards, or closer. And so on.

You know also that, by and large, the bigger guns are used against bigger, slower targets. Sinking a surface target (and if it's a warship it can withstand a lot of pounding) requires the heavy punch of heavy guns. But in bringing down an air target, speed is the thing. A light gun can be brought into action more speedily than a heavy one, and can shift more readily with the target's evasive maneuvers.

The sights (and other fire-control gear) used with a ship's armament must be designed to take care of these requirements.

Specifically, the fire-control equipment for heavy armament is designed primarily for high accuracy because that's the main requirement at long ranges. To obtain such accuracy, the equipment must have powerful optical units and long-range radar.

On the other hand, fire-control equipment for machine gun batteries is primarily concerned with rapid solutions to the fire-control problem (even if the solutions are approximate rather than exact). The optical systems needn't give powerful magnification, but (because of the rapid movement of nearby air targets across the line of sight) they must give wide-angle vision, and the radar must be of a design especially suited to close ranges.

Lead-Computing Sights

The quickest way to get solutions to the AA fire-control problem is to solve the problem in the sight itself. And that is the function of the LEAD-COMPUTING SIGHT.

The idea of performing computations of this kind in a gun sight is not as modern as you might think. We've already mentioned sights of over 50 years ago that compensated for drift and range—that is, if you set such a sight for a given range, it automatically offsets the line of sight to compensate for trajectory curvature due to gravity and drift. Lead-computing sights go a couple of steps further. In the present-day AA fire-control problem, the most important values to solve are LEAD ANGLE and SUPERELEVATION, and those are what modern lead-computing sights yield.

We cannot in this course analyze the functioning of lead-computing sights in detail, but we'll discuss their principles. The Mk 14 and Mk 20 sights are types you'll often encounter on machine gun mounts, and we'll use them as examples.

How Gyros Figure Lead Angles

Consider first how a lead-computing sight figures lead. The heart of the lead-computing mechanism is the GYROSCOPE. All lead-computing sights have one or two power-driven gyros.

Fundamentally, any gyro is a rapidly rotating wheel. While it's rotating, the wheel tends to maintain rigidly the position of its axis in space. When you try to push the axis of a spinning gyro around, it resists. Push harder, and it yields. But when it yields, it doesn't just give way and permit itself to be pushed. It PRECESSES—that is, the wheel's axis of rotation tilts at right angles to the push. (The movement is a lot easier to picture than to describe, so look at fig. 7–6A to see how it works.) If we equip the gyro with restraining springs that tend to return it to zero (upright) position, the amount of tilt will be proportional to the rate of turn (or angular

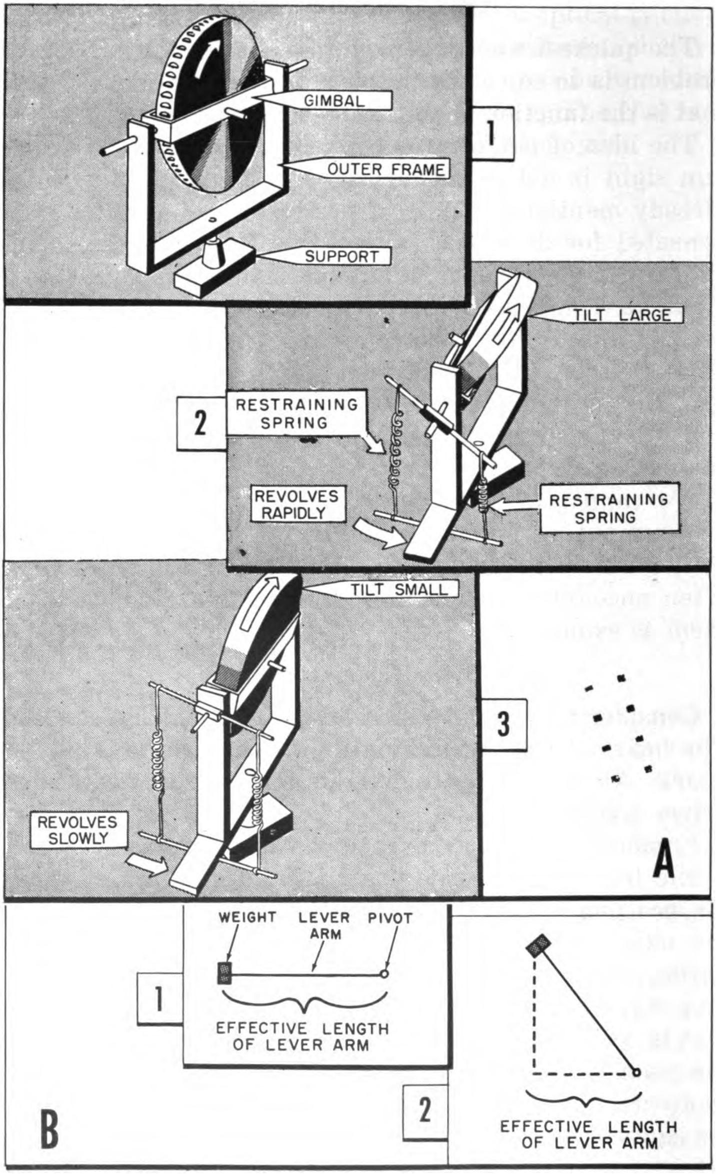


Figure 7–6.—Principles of lead-computing sight. A. Gyro action. B. Superelevation correction.

velocity) of the gyro gimbal frame, and the springs will right the gyro when the turning movement ceases. The Mk 14 sight uses springs, as in figure 7–6A. The Mk 20 uses an electromagnet to do this (fig. 7–7).

Now the required lead angle for a moving air target is the product of the angular velocity of the line of sight and the time of flight of the projectile (which depends on

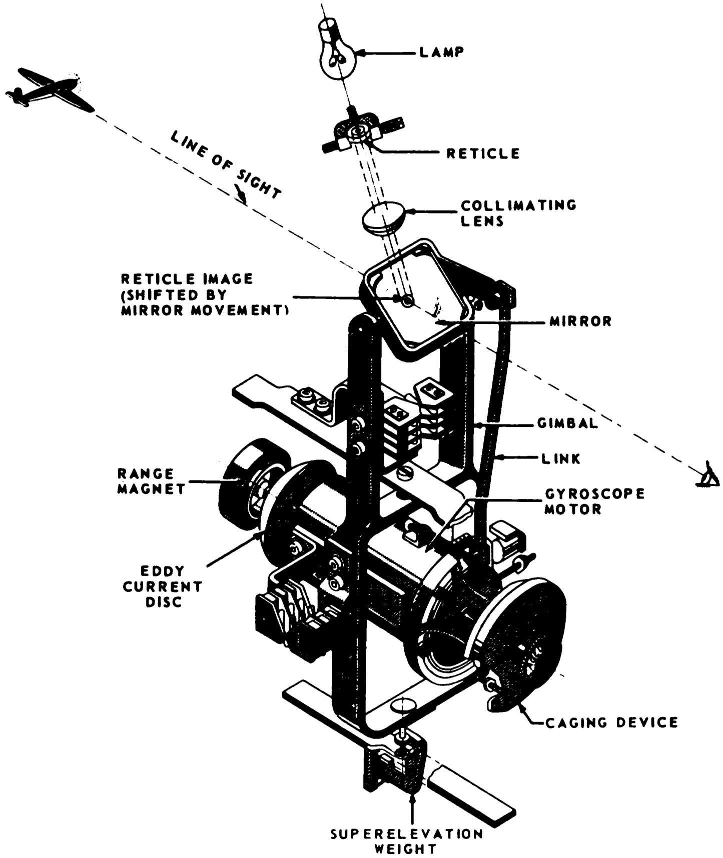


Figure 7–7.—Mechanism of gun sight Mk 20.

range and initial velocity). Suppose we use a gyro like this to give us lead angle. When we track the target smoothly, the gimbal frame turns about the input shaft at the angular velocity of the line of sight to the target. The gyro tilts. Next we adjust the tension of the springs (in the Mk 14 sight) or the current in the electromagnet (in Mk 20) in accordance with the projectile's time of flight to the target. (We slack off spring tension or magnet current for longer ranges, and increase them for nearer targets. The adjustment device is calibrated in terms of range.) Result: the output will then correspond to the required lead angle.

Superelevation Correction

Another mechanism takes care of the superelevation correction. As you remember, the superelevation for any given range decreases with target elevation. The mechanism that regulates this variation in a lead-computing sight is a weight at the end of a lever arm. When the gun (and the case of the lead-computing sight mounted on it) is at zero elevation, the turning effort or torque of the lever arm on the pivot (fig. 7–6B) is at its maximum. When the gun is at high elevation, the lever arm in the sight case is tilted. The effective length of the lever arm (the dotted projection of the arm) is much smaller, and so is its torque exerted at the pivot. Compare this with figure 6–11, which shows how superelevation changes with target elevation.

But remember that this mechanism merely CORRECTS the initial superelevation value for target elevation. The superelevation angle is based initially on RANGE.

So, then, both lead angle and superelevation correction depend on range. But how is range determined?

In lead-computing sights without radar, range must be estimated by a crew member. Since the Mk 14 and Mk 20 are used with relatively short-range machine guns, such an estimate is more accurate than it would be for long ranges. The estimated range is set into the sight by a knob calibrated in hundreds of yards.

Later in this chapter we'll see how radar can more accurately determine range for lead-computing sights than human estimates can.

Functioning of Mk 20 Lead-Computing Gun Sight

Both Mk 20 and Mk 14 sights are used on machine gun mounts. The Mk 14 uses two spring-restrained air-driven gyros (one for elevation, one for train); the Mk 20 uses one electrically driven gyro for both, and is the newer design.

Let's look a bit more closely at the Mk 20 (fig. 7–7), which in principle illustrates the functioning of all lead-computing sights. The gyro and the superelevation lever arm are linked mechanically to a partly silvered mirror. When the gunner looks into the sight, he sees the target and the image of an illuminated reticle. The lamp illuminates the reticle, and the collimating lens makes all the light rays from it parallel, so that the image of the reticle in the mirror seems to be at an infinite distance from the gunner's eye. The gunner tracks the target smoothly, keeping the reticle on target always. (In a lead-computing sight, he NEVER tries to lead the target.) As he tracks, the gyro precesses, and the superelevation lever arm tilts. These actions deflect and tilt the mirror, and shift the reticle image and the line of sight. Thus, as the gunner continues to keep the reticle on target, the gun's bore axis is offset. This offset is the required lead angle and superelevation.

The accuracy of this process depends on, among other things, the range for which the sight is set. In the Mk 14 sight, range is set by adjusting spring tension. In the Mk 20, there is used an electromagnet in whose field a copper-covered disc on the gyro shaft rotates. (See fig. 7–7.) The braking effect of the currents induced in the disc by the electromagnet can be varied by varying the current in the magnet coil. Thus the behavior of the gyro can be adjusted for different ranges by regulating a rheostat (not shown in the figure) calibrated in yards of range, which controls the current in the coil.

The caging device is used to lock the gyro in position while a target is not actually being tracked.

Sights for Larger Guns

In larger and longer range weapons, though a rapid solution to the fire-control problem is still necessary (a slow solution is never an advantage), more time allows a more exact solution. Besides, approximations that aren't a major disadvantage with lead-computing sights permit serious inaccuracies at longer ranges. And accuracy is the primary requirement.

For this reason, sights in larger caliber mounts aren't of the computing type. They merely have the function of providing for very precise offsetting of the axis of the bore from the line of sight. Under normal conditions, target location (elevation, bearing, and range) is determined by a remotely located station. The fire-control problem itself is solved elsewhere, and the gun is positioned in elevation and train by power-driven units under the control of signals transmitted from the point where the fire-control problem is solved.

Well, then, why have sights in gun mounts at all?

There are two main reasons. One is that the gun mount may not always be controlled in the manner described above, because of real or simulated casualty. Another is that watching the target through the sights permits a check on the accuracy and performance of the remote control system.

Figure 7–8 shows in highly schematic form the flow of data through the sighting system of any gun mount from 5-inch up. Different mounts and turrets are different in detail, but this scheme in general applies to all.

Computed sight settings are transmitted electrically to the sightsetter. They usually appear on dials at the sightsetter's station, but may be transmitted by telephone.

Or they may, in local control, come from the mount captain.

The sightsetter cranks in the transmitted settings (usually by matching pointers). These settings, as you know, register on the dials of the sight-setting mechanism, and either move optical parts in the sight telescopes (like the movable prisms in fig. 7–3C), or move the sight telescopes themselves. The pointer and trainer see the shift in their telescopes, and move the gun in train and elevation to get their crosshairs on target. Thus the bore axis is offset by the proper amount from the line of sight.

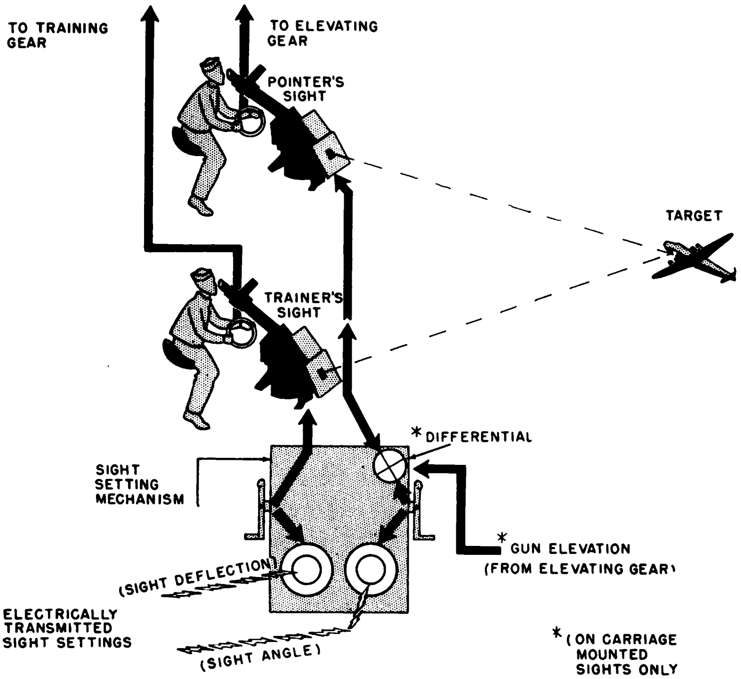


Figure 7–8.—Functioning of sighting equipment on a typical gun mount (3-inch or larger).

All of this you should already know. But notice one other feature—the gun elevation input from the elevating gear. This input is needed only on carriage-mounted sights, because the sights otherwise won't shift as the gun changes elevation. Gun elevation is added to sight angle by a differential gear mechanism to produce in the telescope the proper shift of the line of sight.

CENTRALIZED FIRE CONTROL

The guns on the Navy's big ships have no monopoly on fire control. The operator of any weapon that throws a missile, whether ashore, afloat, or aloft, uses some kind of fire-control technique. But in the Navy some aspects of fire control have always been under centralized control rather than under the control of the gun crew. Even a hundred and fifty years ago, when our Navy was new and gunnery was primitive and limited to very short ranges, ships mounting sizable batteries ordinarily fired them in salvo, at the order of some officer standing at a point of vantage—in the rigging, for example. And as time has passed and ordnance equipment and fire-control techniques have improved, the trend to centralized control has continued so that now not only firing but also the positioning of weapons is controlled from a central point. Yet this trend has not eliminated control of firing and gun-laying at the mount (LOCAL CONTROL), although this is now only a secondary method.

But what advantage is there in centralized control of a warship's guns? What's wrong with letting each gun crew lay and fire its gun independently in local control?

There are several disadvantages to local control. The smoke of their own firing, to say nothing of spray and mist and their position close to the surface of the water, make it difficult for pointer and trainer of the gun mount to see the target. Each gun crew will have to make its own estimates of range, drift, wind, target course and speed, and so on. Some may do this well, but not necessarily all. Some may even fail to identify the enemy, and select the wrong target. Besides, if a number of other weapons are also firing at their target, how can gun crews know if their own shots are hits, or if they're close, or how much or in which direction to apply correction?

Now compare with centralized control, which eliminates

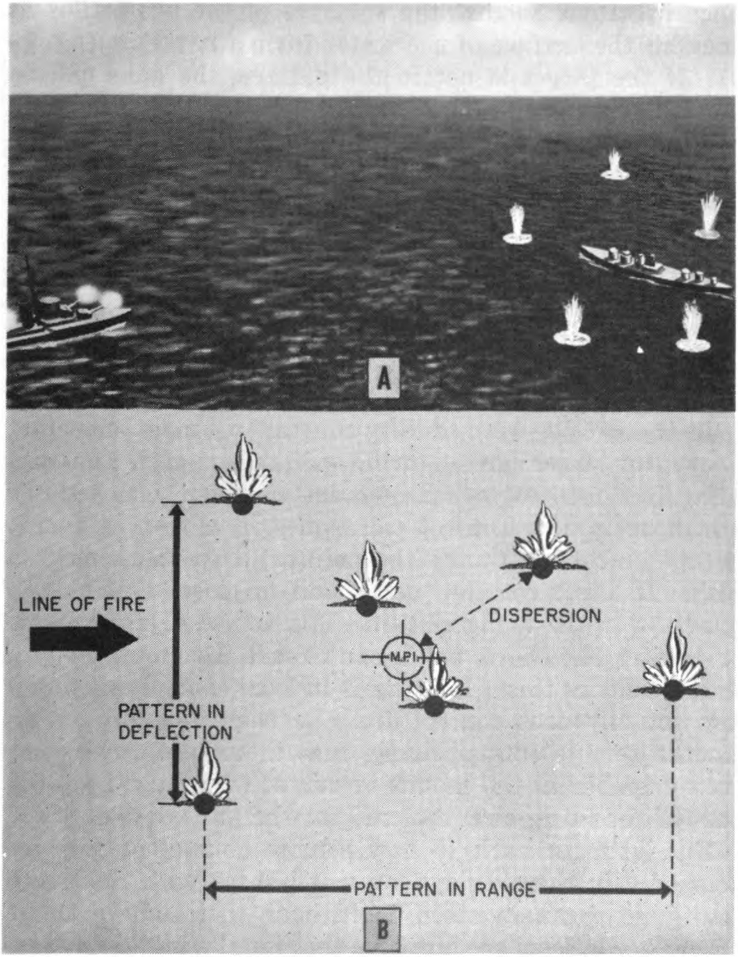


Figure 7–9.—Pattern of a salvo about a target.

all or most of these troubles. The central control point is high in the ship's structure, and has the maximum visibility. Its equipment for identifying and determining the location and movement of the enemy is more efficient and specialized than what you could install in a gun mount, and it is manned by experts in the proper techniques. The guns of each battery or mount or turret can be fired all at once in SALVO, so that the splashes of the projectiles as they hit the surface of the water form a PATTERN (fig. 7–9). If the target is not in the pattern, the guns can be shifted for more accurate laying. In the gun crew, you can do most of these things too—and in local control you MUST know how to do them—but centralized control makes it possible to do them far more efficiently, as you will see.

Let's now examine more closely the techniques and equipment used in centralized fire control. Because it's simpler, let's begin with remote control of firing.

REMOTE CONTROL OF GUNFIRE

In the antique kind of "fire control" we mentioned just above, an officer gave a firing signal, but each gun was fired by a member of its own crew. Even with today's advanced remote control techniques, a mount or turret crew member (normally the pointer) still has a part to play. If fire is remotely controlled, he closes a firing key which is in the firing circuit. The actual firing impulse originates elsewhere, but it can't reach his mount or gun unless he does this. If firing is in local control, his firing key actually does control fire. So bear in mind, as we discuss remote control firing, that there is always some crew member at the mount or turret who must keep his part of the firing circuit closed for the guns to fire.

But let's get back to how remote control of fire developed. In the old days, on small ships with relatively few guns, gunners often could hear their officer shout "Fire!" or at least see him give the signal with his cutlass, but sometimes they couldn't. On bigger ships, where the command to fire in salvo was relayed down the line, exact synchronization of salvos was impossible.

When effective ranges were relatively short, inaccurate fire was relatively easy to correct, and this failure of all guns to fire in exact synchronism wasn't serious. But as ranges increased and fire-control instruments became more precise, ragged salvos made it hard to determine how well the splash patterns approached the target, because they weren't all visible at the same time. What was needed was a signal that could be transmitted to the whole battery at once, so that the whole battery could fire simultaneously. The human voice and the waving cutlass were no longer enough.

Electricity provided the answer. First it was BUZZER FIRE. With a buzzer at each gun mount, closing a circuit at a central point caused all the buzzers to sound at once, and all guns could be fired by a single signal.

Yet this wasn't the final answer. As you know, most guns of the old days were fired by igniting a powder train which led into the propelling charge in the breech. A little later, firing was done by a percussion mechanism to ignite the powder train. Either way, there was some delay and variation in the actual instant of firing. Besides, there were the delay and variation in reaction time of individual members of the gun crews. Buzzers improved matters, but these difficulties persisted. That is why, though the buzzer-type salvo signal is still used, it's a secondary method.

The primary method of firing by remote control is to close a circuit which itself sets off the propelling charge. This is MASTER KEY FIRE. The firing key at the mount must be closed too, and when the guns are ready to fire, it is. But the remotely located key in the same circuit remains open until the right moment. The "right moment" may be selected by a crewman in the fire control director, or it may be selected automatically by a mechanism in the fire-control system. We'll go into that later in this chapter.

In short, the firing impulse can get to the guns in the mount or the battery in a number of different ways. We can recognize several METHODS OF FIRE, or ways in which the firing signal or impulse gets to the guns. In POINTER fire, it's done by the pointer at the gun itself, generally by closing a key that sends an electric current into the gun-firing circuit (ELECTRICAL FIRING), or by stepping on a pedal that operates a firing pin in the gun (PERCUSSION FIRING).

MASTER KEY firing is handled from a control station at some distance from the gun fired, either by somebody operating a key or button, or automatically by a mechanism that closes the firing circuit whenever the ship, as it rolls and pitches, reaches a certain angle.

We also recognize several TYPES OF FIRE (the way in which the firing of one or a number of guns is arranged).

A SALVO is the firing of two or more guns simultaneously on the same signal, at the same target. Salvos are normally fired at regular intervals, which are so spaced as to permit reloading and (where necessary), relaying the guns. Salvos may be fired by entire batteries, or by individual mounts or turrets.

To conserve ammunition, reduce the intervals between salvos, or speed up the process of spotting (to be explained later in this chapter), PARTIAL SALVOS or SPLIT SALVOS may be fired.

The SPLIT SALVO is the firing of less than the full number of guns in a mount or turret. Three 2-gun turrets may participate in a split salvo, for instance, if only one gun in each turret fires. In the PARTIAL SALVO, all the guns in a turret or mount fire at once, but not all the turrets or mounts in the battery participate. That is what happens when No. 1 turret of our 3-turret battery fires both its two guns, while the rest of the battery remains silent.

Batteries do not always have to fire in salvo. In CON-

TINUOUS FIRE, each gun in action fires individually when ready, regardless of whether other guns are ready. When each turret fires individually, whether or not other turrets are ready, we have CONTINUOUS TURRET FIRE.

Other types of fire you should know about are SLOW FIRE, in which firing is delayed to allow application of corrections, or to conserve ammunition, and RAPID FIRE, in which firing is not delayed for these reasons.

There are several ways in which fire can be distributed and concentrated. In DIVIDED FIRE, one ship or battery may engage two or more targets. In SINGLE FIRE the whole ship concentrates on one target. In DOUBLE, TRIPLE, and QUADRUPLE FIRE, two, three, or four ships may concentrate on one target.

REMOTE CONTROL OF GUN LAYING

Remote control of gunfire, valuable as it is, is not the final word in centralized control of armament. For maximum effectiveness, gun laying must be remotely controlled too. The steps in the process are as follows:

1. Determination of target position and movement.
2. Transmission of this information to a computer, which works out how the guns must be laid for hits on the target.
3. Transmission of this information (called GUN ORDERS) to the gun mounts.
4. Control of the gun mounts to lay the guns in accordance with the gun orders from the computer.
5. Correction of gun position on the basis of observed effects of fire. (This is SPOTTING.)

The Fire-Control Director

Remote control of gun laying begins, as we have seen, with locating the target and determining the rate and direction of its movement. In the preceding chapter you learned that target position is determined in terms of RANGE, TARGET BEARING, and (for air targets) TARGET ELEVATION. Similarly, target movement is determined in terms of the RATE OF CHANGE of these three kinds of information

In the modern fire-control system the function of determining target location and movement is performed by a DIRECTOR. For the moment, you won't be too far off base if you think of a director as a "gun sight without gun" whose position in train and elevation with respect to the ship can be very accurately determined. When it's on the target, it establishes the LINE OF SIGHT to the target. The director also is fitted with TRANSMITTERS which can convey signals corresponding to its position to the other parts of the fire-control system.

Those are the essentials of the director. All directors have them.

Directors with Lead-Computing Sights

The smallest director is the one used with the 40-mm battery—namely, the Mk 51 (fig. 7–10A). This is actually a pedestal, containing position transmitters and provision for power supply on which is mounted either a Mk 14 or a Mk 15 lead-computing gunsight. (The obsolescent Mk 14 is being replaced by the Mk 15. The Mk 20 is not now used for directors; you'll find it only on 20-mm gun mounts). As you remember, lead computing sights not only establish the line of sight to target, but also solve the fire-control problem by computing superelevation and lead angle, and add these values as offsets to the line of sight. Thus, when used on a director, such a gun sight transmits, to the battery it controls, electrical signals which denote the position that the guns must take for their projectiles to hit the target. The ordered gun position in elevation is called GUN ELEVATION ORDER; the position in train is GUN TRAIN ORDER. All gun directors with lead-computing sights transmit gun orders.

The Mk 15 sight is also used with a different director—the Mk 52. Figure 7–10B shows the Mk 52 with radar installed. The Mk 51 director may also be used with radar, though the radar units themselves are not installed

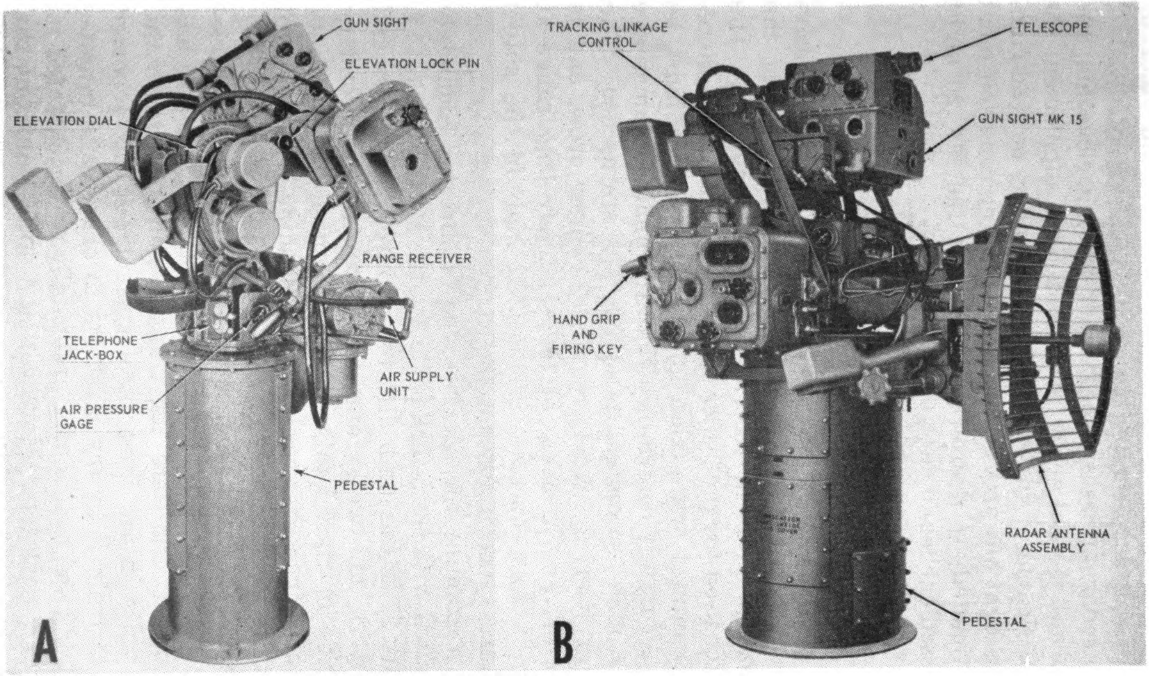


Figure 7—10.—Lead-computing sights as gun directors. A. Mk 51 director with Mk 15 sight. B. Mk 52 director with Mk 15 sight (and radar).

on the director. Later in this chapter we'll briefly discuss the fire-control systems that utilize these and other directors with lead-computing sights.

The radar unit establishes target bearing, elevation, and range, and is used either instead of, or to supplement the optical system of the sight. Without radar, no lead-computing sight has provision for determining range; it must be estimated by a crewman, as with the Mk 20 sight discussed earlier.

The Mk 37 Director

As you remember from earlier in this chapter, in heavier caliber armament the ACCURACY of solution of the fire-control problem receives the main emphasis. The director used for the 5-inch battery on a warship is therefore equipped with telescopic optics. Range must be more accurately determined than the unaided human eye can estimate, so optical RANGEFINDERS are needed. The director itself is bigger, requires a larger crew, and is power driven. Because of the relatively long range at which it must operate, it's located high in the ship's structure. And it's armored.

Let's examine the specific type of director commonly associated with the 5-inch battery—the Mk 37 (fig. 7–11). The Mk 37 is the main director on aircraft carriers and destroyers, and two to four Mk 37's control the secondary batteries on capital ships. It can be used to control 40-mm and 3-inch fire, while on larger ships it can control turret fire in emergency.

The Mk 37 has a telescopic TRAINER'S SIGHT, a telescopic POINTER'S SIGHT, and a RANGEFINDER. It also has electrical transmitters for transmission of data to the other units in the fire-control system. It has a power drive to train it in any direction to observe its targets. The sights and rangefinder are usually power operated in train and elevation. Moreover, the optical units of the director are kept level by power drives so that as the ship

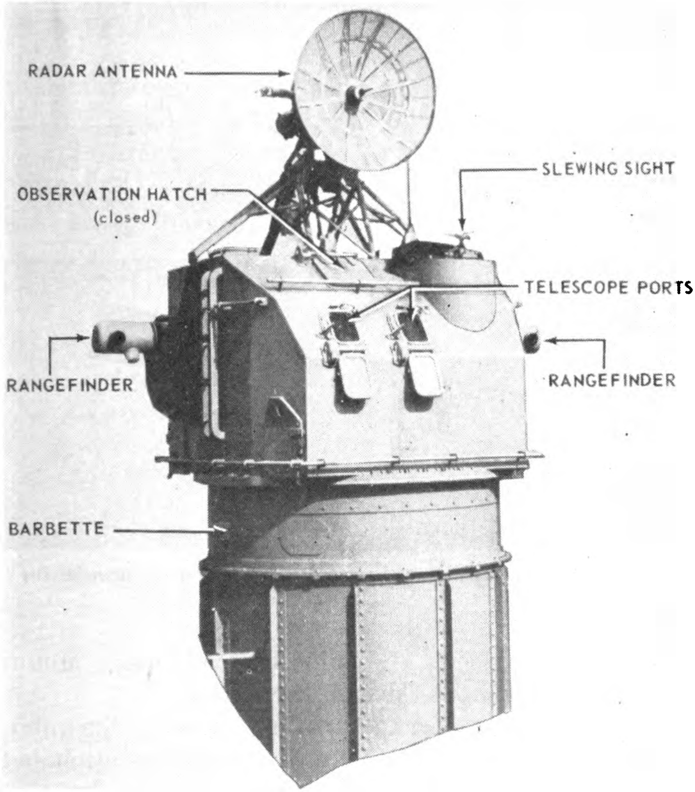


Figure 7–11.—Mk 37 director.

rolls and pitches, the horizontal crosshairs in their reticles remain horizontal (fig. 7–12).

And, of course, the director must be mounted as high on the ship as the superstructure will permit. Directors, because of their exposed position, are generally armored. Secondary-battery directors carry thinner armored shields.

The Mk 37 director is mounted atop a cylindrical BARBETTE. The RANGEFINDER sticks out from either side of the director housing. There are two ports in the sloping

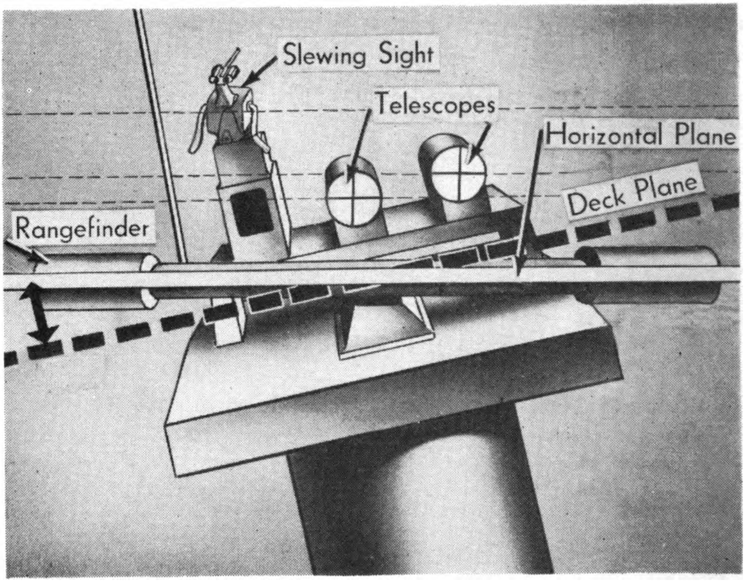


Figure 7–12.—Optical elements of the Mk 37 director are automatically kept level.

front for the trainer's and pointer's telescopes. Mounted on the director's top is the RADAR ANTENNA.

There is an OBSERVATION HATCH just below the antenna structure. To its left, at the control officer's station, is the SLEWING SIGHT, which is used to train and elevate the director at a high rate of speed, to place the director line of sight on a new target rapidly, or to shift from one target to another.

Machine gun directors like the Mk 51 and Mk 52 are located rather close to the guns they control. But the Mk 37 may control mounts distributed over much of the length of the ship, and it's located at a considerable height. This introduces the problem of PARALLAX.

Parallax may be either VERTICAL or HORIZONTAL. Because the distances involved are greater, horizontal parallax is the more serious. To understand what we mean by horizontal parallax, look at figure 7–13. Notice how the line of sight from the director amidship converges with the lines of sight from the gun mounts near the bow or stern, meeting it at the target. In other words, neglecting ballistic corrections, the lines of sight of guns and director cannot be paralleled if they are all on target.

The horizontal angle between the gun's bore axis and the director's line of sight is the HORIZONTAL or TRAIN PARALLAX. The further the gun from the director, the greater the parallax angle for any given range. But as range increases, parallax decreases.

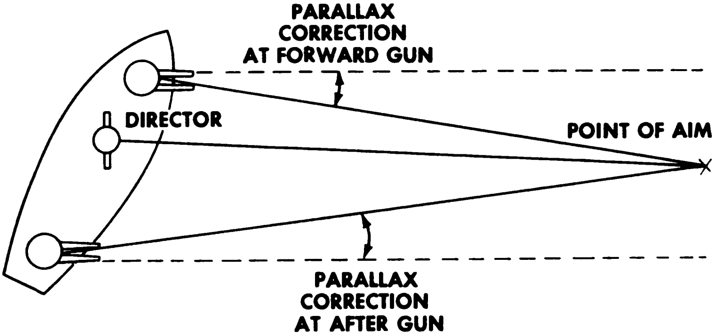

PARALLAX CORRECTION AT FORWARD GUN
DIRECTOR
POINT OF AIM
PARALLAX CORRECTION AT AFTER GUN

Figure 7–13.—Horizontal parallax.

Although horizontal parallax correction is different for each mount, depending on its distance from the director, the parallax correction computed in the fire-control system and transmitted to all gun mounts for any given range is the same. It is a correction (UNIT PARALLAX CORRECTION) based on the assumption that the gun mount is just 100 yards from the director. In each mount a set of CHANGE GEARS converts this unit correction to the proper correction based on the actual horizontal distance of the director from that mount.

Fire-control systems may also compute parallax corrections for the vertical distance between guns and director. This is VERTICAL PARALLAX, and it is about the same for all gun mounts because all are at more or less the same level.

Optical Rangefinders

One of the main differences between the directors using lead-computing sights and the Mk 37 and main battery directors is that the former have no OPTICAL devices for determining range. In secondary-battery directors like the Mk 37, and in main-battery directors, this job is done by the RANGEFINDER.

The rangefinder is a long metal tube with eyepieces at its center and a window near either end. The tube may be up to 40 feet in length. Inside the tube are lenses, prisms, reticles, and other optical parts, plus precision mechanisms for moving some of them. Rangefinders are shown in figures 7–11, 7–12, and 7–15.

In this course we can't go very deeply into the complexities of fire-control rangefinders, but you should know something about them. You'll find optical rangefinders not only in secondary-battery and main-battery directors, but also in some major-caliber turrets, where they are intended for use in local control.

There are two types of rangefinder—the STEREOSCOPIC (which is more frequently used) and the COINCIDENCE.

Every two-eyed human has stereoscopic vision. To see how it works, try this little exercise:

Hold an arm straight out horizontally. Raise your index finger. Now move the finger slowly toward your nose, keeping both eyes on it. By the time the finger reaches your nose, the "lines of sight" from your eyes to your finger converge sharply (fig. 7–14A).

Next, look at some object 2,000 yards away. Now the lines of sight for the two eyes are practically parallel.

Obviously, then, the closer the object, the greater the convergence; the farther away, the more nearly parallel the lines of sight become.

Measuring the convergence of the lines of sight actually provides a means of measuring range. But the distance between your two eyes is small, and it's difficult to

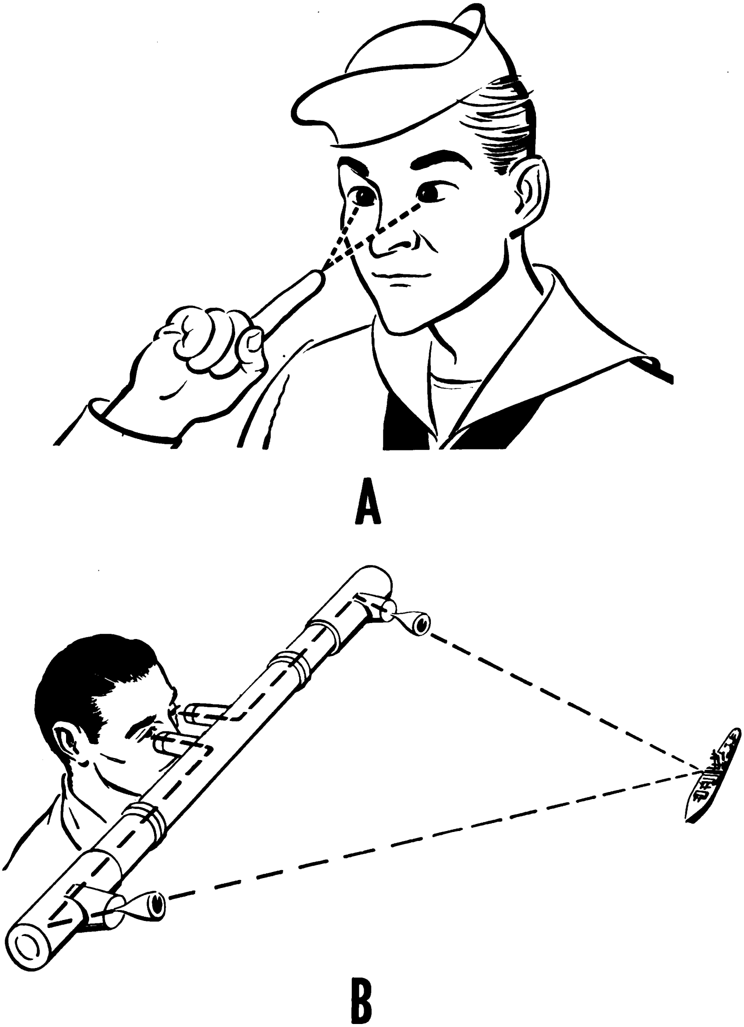


Figure 7–14.—Principle of the optical rangefinder.

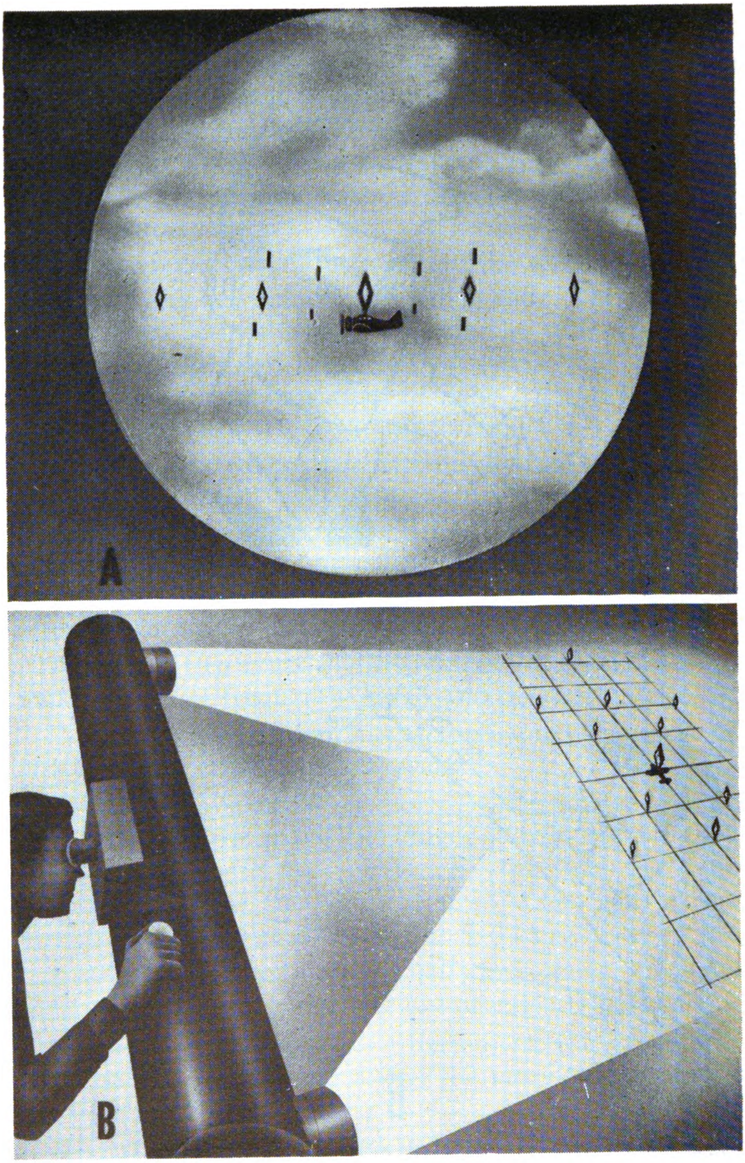
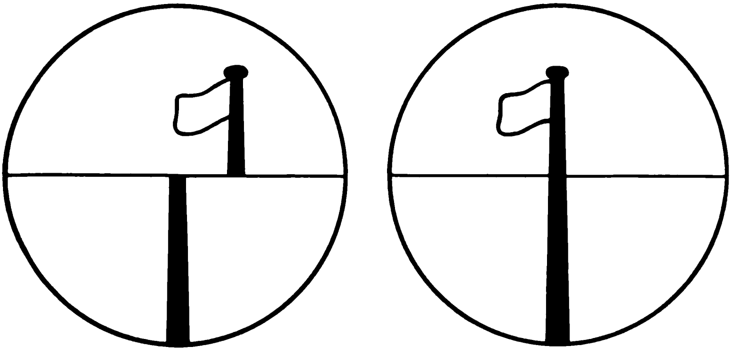


Figure 7–15.—Stereoscopic rangefinder. A. Reticle pattern. B. Measuring range.

get the swiveling of your eyeballs to register on a dial where it would be easy to measure. So the optical system of a rangefinder in effect separates the rangefinder operator's eyes (fig. 7–14B) by a distance equal to that between the rangefinder's apertures. When the optical parts in the instrument are moved to get its lines of sight to converge on the target, the amount of movement registers on a dial calibrated in yards of range. The rangefinder also magnifies, like a telescope—but with a super 3-D effect.

In the stereoscopic rangefinder, the reticle pattern is composed of RANGING MARKS (fig. 7–15A) apparently floating in space at various distances. In operating the rangefinder, the observer turns a knob until the large diamond at the center of the pattern seems to be superimposed upon, and at the same distance as, the target (fig. 7–15B). Then the range can be read directly off a dial in the rangefinder. (The smaller diamonds in the pattern, which seem to float in space at different ranges, are used in spotting.)



IMAGES NOT IN COINCIDENCE
(A)

COINCIDENCE ACHIEVED
(B)

Figure 7–16.—Coincidence rangefinder image.

Now for a word about the COINCIDENCE RANGEFINDER. This name refers only to the image you see in its eyepiece. Externally, the instrument looks much like the stereoscopic type. But when you look into the eyepiece, you see (fig. 7–16) an image split horizontally across the middle, and the upper and lower halves are displaced. You twirl a knob to match the two halves; when they're matched, you read the range off the dial.

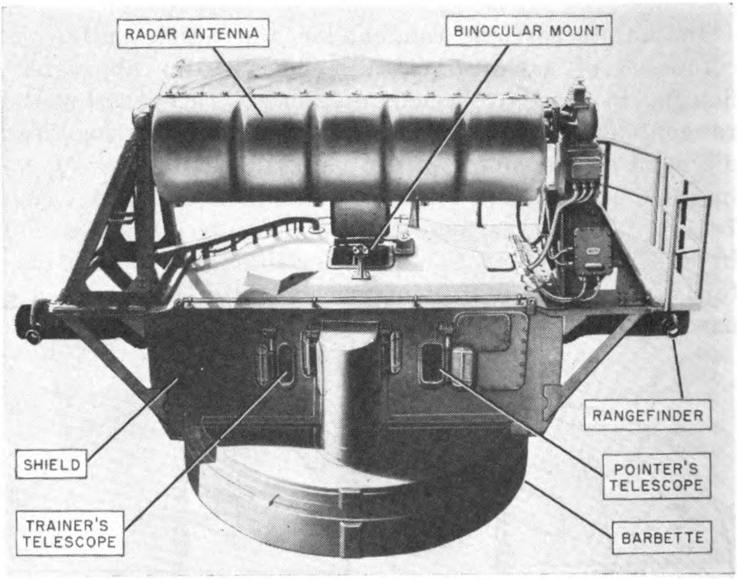


Figure 7–17.—Main-battery director (Mk 34).

Although the coincidence rangefinder is easier for a novice to operate, it doesn't do as good a job as the stereo type with a really expert operator, and it is not so well adapted for fast-moving targets like aircraft. Besides, it is just about useless for spotting. That's why the stereo type is more widely used.

Now you have a general idea of what the Mk 37 director is and does. Now let's glance at a main-battery director.

Main-Battery Director

A typical main-battery director is the Mk 34, used on *Baltimore* class cruisers (fig. 7–17). Like the Mk 37, it's equipped with radar (the antenna is completely concealed inside a housing above the directors shield), long-range optical rangefinder, and pointer's and trainer's telescopes. The optical and radar units are power-driven to keep them horizontal. However, the Mk 34 is not designed primarily for dealing with high-speed air targets. The main battery can engage such targets, but when this happens it is usually switched to the Mk 37 system.

SYNCHROS AND SERVOS

We've just discussed a number of gun directors. But these units aren't complete and independent of themselves. They are each part of a FIRE-CONTROL SYSTEM, the main elements of which are separated from each other by some distance. Since that's so, how can we get the director's information on target location and movement to the gun mount and to the other elements of the fire-control system? More than that, how can we get mount power drives to lay the guns in accordance with the solution to the fire-control problem?

The brief answers to these questions are very simple. We transmit information between the elements of the fire-control system by means of SYNCHROS. Moreover, the synchros often control SERVO SYSTEMS, which lay the guns in accordance with the solution to the fire-control problem.

But the words "servo" and "synchro" each denote ideas and equipment of some complexity. This book won't make you an expert but if you understand the fundamentals, you'll have a much better idea of how the elements of Navy fire-control systems work together and how the guns in your mounts are aimed by remote control. Synchros and servos are often (though not always) used together. Let's start with synchros.

Synchros and Synchro Systems

Synchros don't come as individual units, but as systems. In this course, up to now, we've vaguely identified synchro systems as "data transmission systems." But from now on they'll be called by their right names. By the way, in certain OP's and in commercial publications issued by various synchro manufacturers, you'll find names like "Selsyn," "Autosyn," or "Teletorque." But they're all the same as "synchro," which is the proper Navy name.

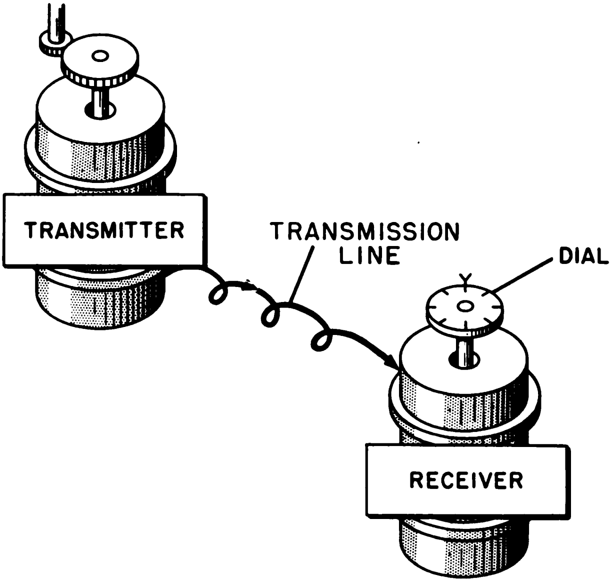


Figure 7–18.—Elementary synchro system.

In its most elementary form, a synchro data transmission system (fig. 7–18) consists of a

1. SYNCHRO TRANSMITTER (formerly called synchro generator).
2. TRANSMISSION LINE.
3. SYNCHRO RECEIVER (formerly called synchro motor).

Synchro transmitters and receivers look very much like ordinary small electric motors. Inside each synchro receiver or transmitter is a rotating part, like an armature, called a ROTOR. The nonrotating part is the STATOR. And here is the important feature: when the system is energized, the rotor of the receiver turns until it is in the same position with respect to its stator as the rotor of the transmitter with respect to its stator.

You can see how useful this is for transmitting fire-control data all over the ship. When the operator of a Mk 51 director tracks his target, the case of his Mk 15 sight is so laid that if it were a 40-mm gun, its projectiles would hit the target. With synchro transmitters geared to the sight to pick up its movement in elevation and train, dial-equipped synchro receivers (often called SYNCHRO REPEATERS) at the mount would show the director's position (fig. 7–20A). Or they could control the mount power drive to position the gun—and this is what actually does happen.

But let's get back to the synchro receiver that has a dial to indicate gun elevation or train order. To make things simpler for the trainer and pointer at the gun, the synchro indicator dial may have surrounding it a larger dial showing the train or elevation position of the gun. Then all the gun crew has to do is to match pointers at the two dials. You are already familiar with this idea.

There are two types of dial mechanisms that are specifically designed for pointer-matching. They are illustrated in figure 7–19, which shows a pair of gun elevation dials indicating that the gun mount (in this case a 5"/38 twin) is matched up with elevation gun order at 0° elevation (read on the dials as 2,000 minutes).

One of these is the FOLLOW-THE-POINTER dial. (Right, in fig. 7–19.) The inner dial shows the synchro receiver's position. The ring dial shows the position (CORRECTED RESPONSE) of the mechanism which is supposed to follow the synchro's indication. When the index marks on the

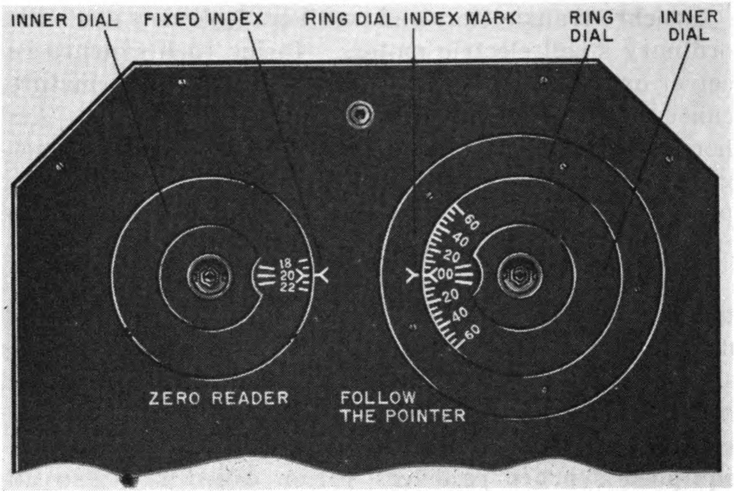


Figure 7–19.—Synchro receiver indication mechanisms.

two dials are matched, the mechanism is in the position indicated by the synchro.

The other synchro-driven dial indication system is called the ZERO READER. Here you match the index mark on an inner dial with a fixed index. (Left, in fig. 7–19.)

The important thing about the zero reader is that the synchro stator (the part that DOESN'T turn in response to an electrical signal) is not fixed, but actually forms the center part of a gear which is mechanically linked to the corrected response. As a result, the stator's position depends on the position of the mechanism to be controlled by the synchro.

To see how this system works, suppose that the synchro rotor turns the zero-reader dial 10°. To follow this indication, the mechanism that is being controlled must then be turned 10°. As the mechanism turns, it moves the stator. The rotor and the zero-reader dial move with the stator, BACK TOWARD THE ORIGINAL POSITION. When the indexes are matched, the mechanism is in the position indicated by the synchro receiver.

Where very high transmission accuracy is wanted, you find that synchros are set up in pairs, one COARSE, the other FINE. This is called a DOUBLE-SPEED system. In synchro dial mechanisms, such a pair may consist of a zero reader for coarse indication and a follow-the-pointer dial for the fine (as in fig. 7–19), or of two follow-the-pointer units.

By using another kind of synchro unit in place of the synchro receiver, the signal transmitted can register at the receiving point as an electrical voltage which can directly control an electronic amplifier which in turn controls a power unit. This synchro device is a SYNCHRO CONTROL TRANSFORMER. (See fig. 7–20B.) The advantage of this arrangement is that the friction which reduces the accuracy of a mechanical indicating device like a synchro receiver is not a factor in the functioning of a synchro control transformer. The rotor of the synchro control transformer (often abbreviated as synchro CT)

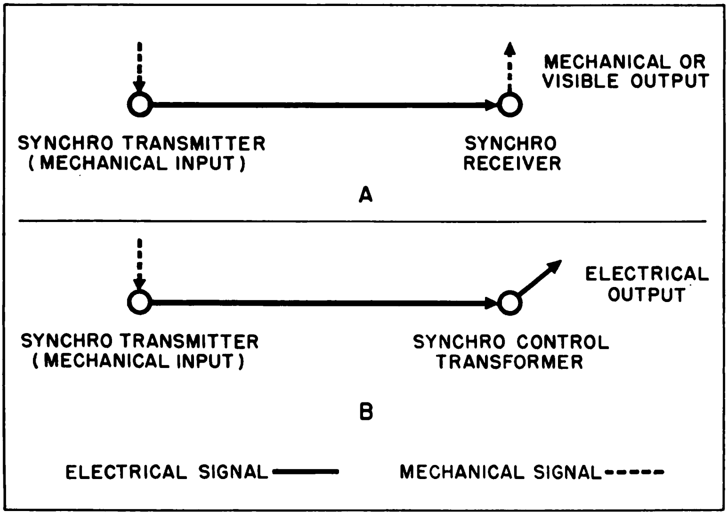

MECHANICAL OR VISIBLE OUTPUT
SYNCHRO TRANSMITTER (MECHANICAL INPUT)
SYNCHRO RECEIVER
A
ELECTRICAL OUTPUT
SYNCHRO TRANSMITTER (MECHANICAL INPUT)
SYNCHRO CONTROL TRANSFORMER
B
ELECTRICAL SIGNAL
MECHANICAL SIGNAL

Figure 7–20.—Synchro transmission systems. A. Transmitter and receiver. B. Transmitter and synchro control transformer.

is mechanically rotated by an outside unit (often a small motor or a gear train from a power drive).

An application of this setup will be discussed in the next section of this chapter.

This by no means exhausts the subject of synchros and synchro systems. There are several kinds of synchro units not described here, and many varieties and combinations of circuits utilizing synchros. But if you know this much about synchro transmitters, receivers, and CT's, it will help you understand the place of the synchro system in the fire-control devices you have to deal with.

Servo Systems

The idea of the servo system or SERVO LOOP is fundamental but not difficult to understand. It's simply a way of getting a weak signal to control much larger forces to achieve some desired result with great precision.

Take one example, a 40-mm gun mount in which a servo loop drives a gun in elevation or train in accordance with a synchro signal. In figure 7–21, the synchro unit (which actually includes two CT's operating as a double-speed system) receives as an electrical synchro signal the gun order signal transmitted from the director. It also receives as a mechanical input through a gear train the actual position (labeled RESPONSE) of the gun mount in elevation. (The setup for train is separate, but similar.) Depending on the amount and direction of the discrepancy or difference (here labeled ERROR SIGNAL) between the gun order signal and the response, the CT output is in a certain direction and of a certain magnitude. But the output is not large enough to operate the stroke motor (which controls the hydraulic power drive), so it's amplified, and the amplifier's output, which depends on the input signal from the CT's, drives the stroke motor. In turn, this operates a pilot valve which operates a booster piston. This in turn sets the position of a hydraulic A-end, thereby controlling its output to a B-end which actually drives the mount. As the mount is driven

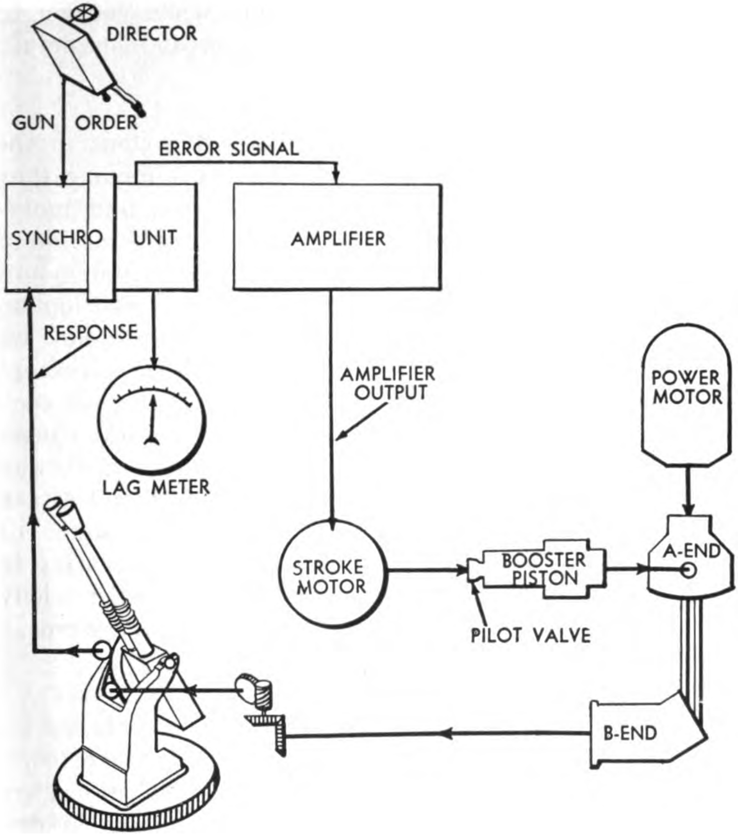


Figure 7–21.—Application of servo loop idea to control of a 40-mm mount.

to elevation gun order position, the signal to the amplifier drops to a minimum (NULL) and the other units in the chain reduce their outputs accordingly until at synchronism (when gun position matches gun order) the outputs all along the line are zero.

The lag meter displays the amount by which gun order and gun position differ.

That gives you the idea of the servo loop, and, in simplified form, an application of it to a gun mount. Actually, a number of important refinements have been omitted, some of which you'll learn more about when you get to study gunmount power drives and controls in more detail.

FIRE-CONTROL SYSTEMS

Early in this chapter, we discussed five steps in the process of gunlaying by remote control. In summary, they were (1) determination of target location and movement, (2) computation of gun orders, (3) transmission of gun orders to a gun mount, (4) control of gun mount power drives, and (5) adjustment of gun position on basis of observed effects of fire (spotting). Up to now we have discussed at least one way to do each of these (except (5), which will come later), and we have discussed such individual kinds of fire-control gear as sights, rangefinders, directors, synchro transmission equipment, and servos. But fire control aboard a Navy ship isn't a task for individual crewmen operating individual items of equipment. It's a task for TEAMS or CREWS operating in teams who operate fire-control SYSTEMS. Let's briefly take up some of the more important fire-control systems.

RELATIVE-RATE SYSTEMS

Relative-rate fire-control systems are those based on directors using gyroscopic lead-computing sights or computing mechanisms. The important ones now in use are the Mk 56, the Mk 57, and the Mk 63. We'll briefly discuss the simplest of the three, the Mk 63, as a more or less representative sample, and even more briefly mention the main features of the others.

The Mk 63 gun fire-control system (GFCS) consists of a gun sight Mk 15 or Mk 29 mounted on a director pedestal, a radar antenna mount (on the gun mount), radar equipment, a wind transmitter (through which wind correctors are introduced), a target acquisition unit or TACU (for locating targets), and, if the guns are sufficiently distant from the director, a train parallax corrector.

Figure 7–10A illustrates the director with gun sight

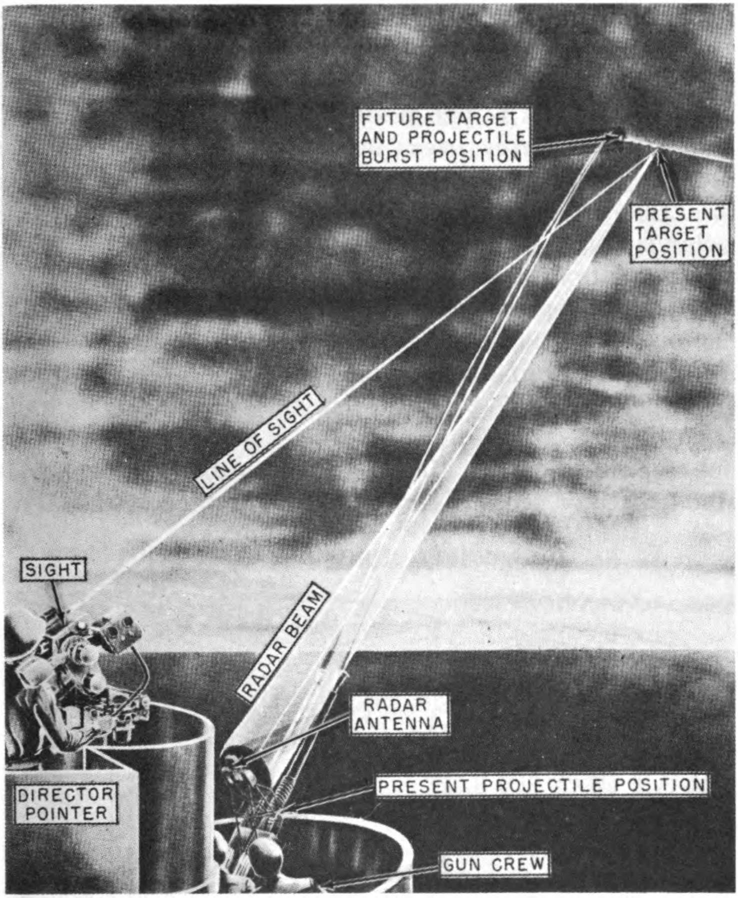


Figure 7–22.—Mk 63 gun fire-control system. AA fire with system, using radar tracking.

mounted, and figure 7–22 shows how it is used in conjunction with radar. As we have seen earlier in this chapter, the Mk 15 sight itself has no provision for determining range optically. But when this sight is used in the Mk 63 GFCS, the radar provides range and other information.

The below-decks components of the system (target acquisition unit, wind transmitter, and radar) are not shown in figure 7–10, but figure 7–22 will give you some idea of how the system works. The director pointer gets his target in his reticle pattern (either a radar blip or optical image can be used), and tracks it smoothly. The radar operator (below decks) cranks into a transmitter the range information that he gets from the radar. (If radar is not in use the director operator estimates range and the rate of change of range and cranks it in.) The Mk 15 sight computes the gun orders, which go to the gun mount. But the radar on the gun mount has its own elevation and train drives, which function to keep its beam on target (as fig. 7–23 shows) as they respond to signals from the director station.

Later mods of the Mk 63 GFCS substitute the Mk 1 Mod 0 director pedestal for the Mk 51, and the Mk 29 sight

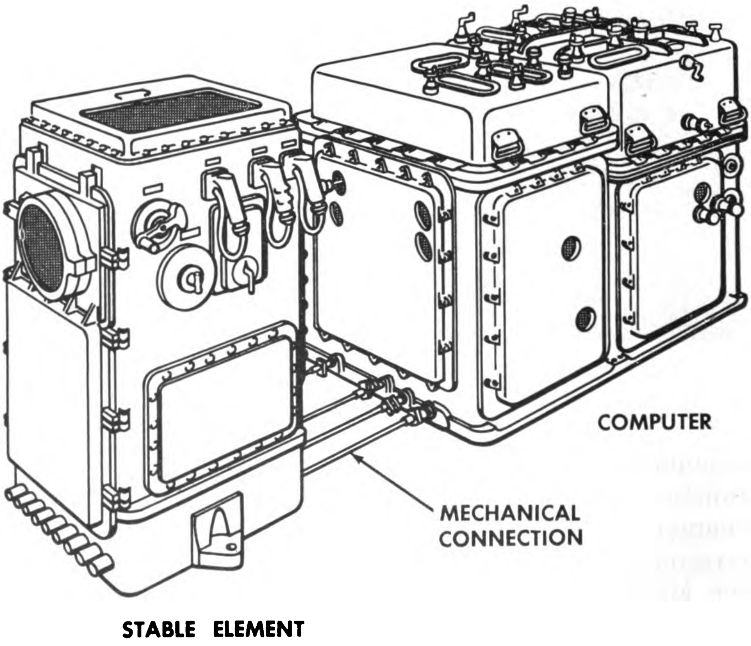


Figure 7–23.—Mk 37 fire-control system: Stable element and computer.

for the Mk 15. These permit improved correction for ship's roll, and make possible accurate tracking of higher speed targets than the Mk 15 sight is built to deal with.

The Mk 57 GFCS is a more elaborate setup, with the radar right on the director, a different method of developing gun orders from gyro tilt, a separate computer for introducing most of the corrections, and other refinements. It can effectively control gun mounts as heavy as 5-inch.

The Mk 56 GFCS has a power-driven director (the only relative-rate system that has one) with a radar antenna on it, can control gun mounts and turrets up to 6-inch, and has the "lead-computing" mechanism set up as a separate computer—not, as with other relative-rate systems, as part of the director. In this respect it somewhat resembles the Mk 37 system, which we'll take up next.

DUAL-PURPOSE FIRE-CONTROL SYSTEM: THE MK 37

The Mk 37 system, which is primarily designed to control the firing and aiming of 5"/38 dual-purpose guns, is widely used in destroyer main batteries, and in secondary batteries of many battleships and cruisers.

The main units of the system (outside the gun mounts) are:

1. Mk 37 director (from which the system gets its name).
2. Mk 1A computer.
3. Mk 6 stable element.
4. Mk 25 radar.

Here is what the system does:

1. Provides signals for positioning the guns automatically and continuously.
2. Operates automatic fuze setters.
3. Provides (as required) continuous, selected level, and selected crosslevel fire. (These will be explained in the next few pages.)
4. Provides synchro signals for continuous sight angle and sight deflection indication at the gun mounts.

Let's look a little more closely at the components of this system. We've already taken a quick look at the director. How about the others?

The Computer

Actually, we can't say much about the workings of the computer here, because it's beyond the scope of this course. Think of it as a big metal box (fig. 7–23) with dials and cranks on it and a series of mechanical brain cells inside (it's not an electronic wonder, as some other computers are), and concentrate on what it does:

1. From certain input information, it computes a continuous solution to the fire-control problem.
2. The solutions take the form of continuous outputs which can control gun laying, director operation, and sighting (both at the gun mounts and at the director).

The Stable Element

In the foreground of figure 7–23 is the inseparable companion of the computer—the stable element. In the farflung Mk 37 system, only these two units rely on solid mechanical connections. All the others are linked by transmission lines and synchros.

To understand what the stable element does, look at figure 7–24. You see a ship upon the sea, and like a real ship on the real sea, it pitches and rolls in a complex motion with the surface movements of the water. If you consider these movements as related to the line of sight of the director, you can divide them into two components: changes in LEVEL (that is, in the same direction as the line of sight) and changes in CROSSLEVEL (that is, at right angles, across the line of sight).

In all our previous discussions, we have pretty much neglected these continuous changes in level and crosslevel. At short ranges and with fast-moving targets like aircraft, they are relatively unimportant, which is why they can be neglected. But in the Mk 37 system and others that deal with longer ranges, they must be taken into account.

It's impossible to stop the movements of the sea. It's not practical to stabilize a warship's hull so that it won't pitch and roll. But we can get the fire-control system to deal with the problem by adding level and crosslevel movements as corrections to the solution of the problem. First, the exact amount of these changes with respect to the horizontal must be determined. Two ways have been used to determine them.

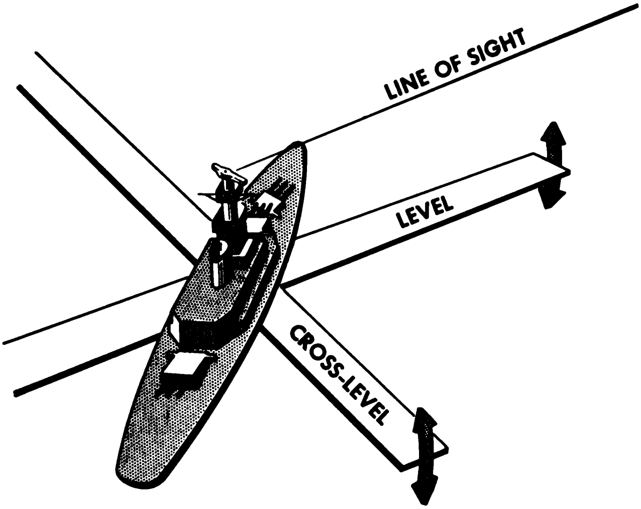


Figure 7–24.—Level and crosslevel.

One is to sight on the horizon. A line of sight to the horizon is depressed very slightly below a true horizontal plane. The amount of depression depends on the height of the observer above the water, and is known with great precision, so the correction to put the line of sight into a horizontal plane is easy to add. In the Mk 34 director there is a special telescope for sighting on the horizon for the crosslevel correction.

But sighting on the horizon is a secondary method for determining a horizontal plane. The primary one is to use a gyroscopic device—the STABLE ELEMENT. (Main-battery fire-control systems use a STABLE VERTICAL, which is similar in principle but different in detail.) In the stable element the gyro remains erect to define the vertical (and hence the horizontal) plane, and the level and crosslevel angles are "picked off" from it by electromagnetic units. Of course, the level and crosslevel angles are (fig. 7–24) with respect to a line of sight on a specific bearing, so target bearing is an input to the stable element, and its outputs are level and crosslevel.

There are two general methods of using the level and crosslevel angle values. With the synchro system, these values can be used to keep the guns laid continuously to land shots on target (for CONTINUOUS FIRE). The ship may roll, pitch, yaw, and weave around, but the guns will remain fixed in their attitude, except to allow for movement of the target, and can be fired at any time.

Or, when roll and pitch are heavy and guns cannot elevate enough to reach the required elevation (this is true of main battery guns of limited elevation), a certain selected value of level or crosslevel is cranked into the stable element. The guns are fired automatically by the stable element or the leveler in the director when, as the ship rolls or pitchs, the actual gun elevation momentarily agrees with the selected value (SELECTED LEVEL FIRE or SELECTED CROSSLEVEL FIRE).

The same principle can be applied to fire the guns automatically at a selected angle of train, as the ship turns (SELECTED TRAIN FIRE).

Fuze Setters

As you know, many projectiles are fitted with time fuzes. These must, before they are fired, be set to explode at the right time. This is done by the FUZE SETTER, which is a part of all fire-control systems designed for batteries 5-inch and larger.

The fuze setting is transmitted by synchro to the FUZE

SETTER at the gun mount. This may be located at any of several places. For example, some mounts and turrets have it in the projectile hoist. It may be in the gun slide. Or it may be a separate unit containing three fuze-setting pots, mounted on the gun carriage behind the pointer. All types are controlled by **FUZE-SETTING INDICATOR-REGULATORS** (fig. 7–25).

Each fuze-setting indicator-regulator can provide automatic or manual fuze setting. Manual control is governed either by matching dials, or by positioning them at the required setting. The instrument is normally set by remote control from the computer.

The **SELECTOR** sets up the indicator-regulator either for automatic or manual control. The **HAND CRANK** is linked

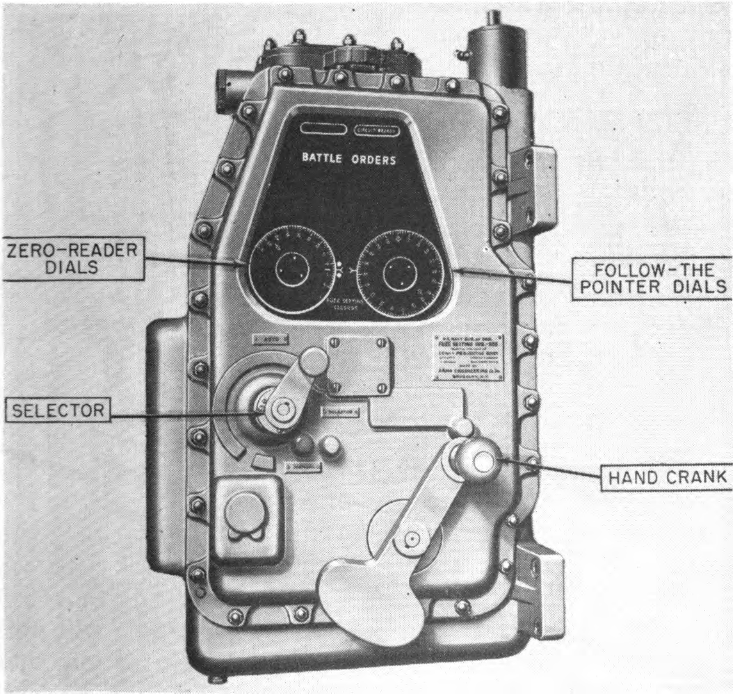


Figure 7–25.—Fuze-setting indicator-regulator.

to the fuze setter mechanism only when the selector is set for manual. You then crank to match the dials, or to position them as required.

The zero reader dials and the follow-the-pointer dials are coarse and fine reading respectively. The inner dial of each group is attached to its corresponding synchro shaft, and bears a single index mark. Each ring-dial graduation represents one second on the zero-reader and 1/50 second in the follow-the-pointer dial.

The Mk 37 System as a Whole

Now let's look at the Mk 37 fire-control system as a whole. First, consider its geography (fig. 7–26).

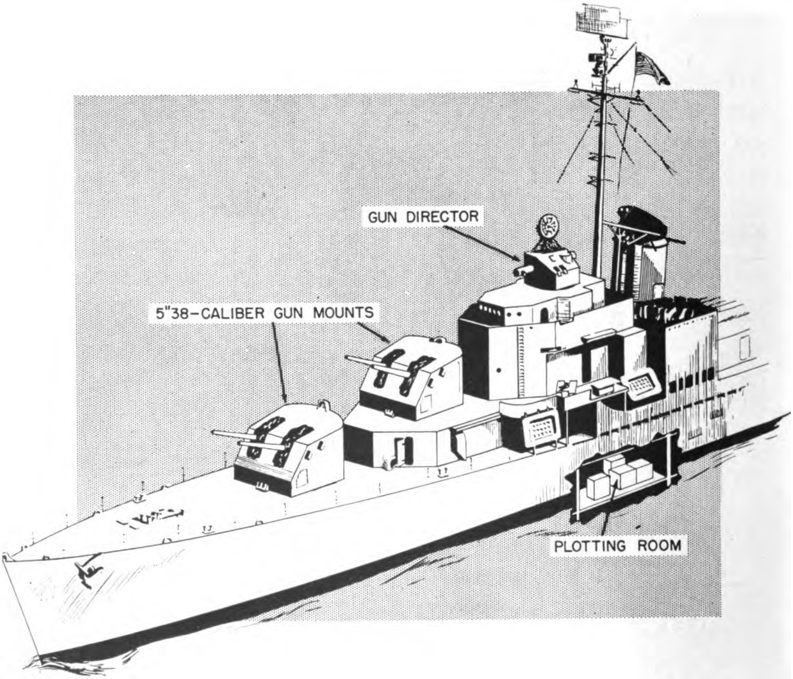


Figure 7–26.—Location of elements of Mk 37 system on a DD.

The various major units of the system are located where they will do the most good, and come to the least harm. The director, as we have seen, must be aloft (fig. 7–26). But computers and stable elements need not be near either directors or guns (thanks to the synchro transmission system), and you will find them below decks in protected plotting rooms, where enemy gunfire won't easily reach them. They do have to be physically close to each other, since they are mechanically interconnected. You'll always find them operating as a pair.

To help you visualize the system in operation, look at figure 7–27, which shows you the flow of all data and positioning orders.

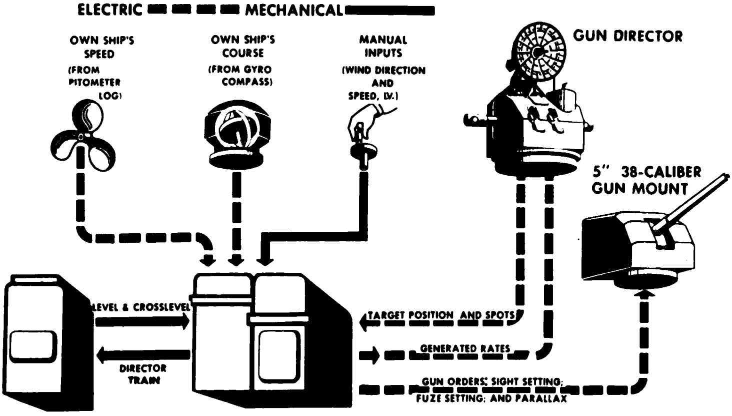

ELECTRIC
MECHANICAL
OWN SHIP'S SPEED (FROM PITOMETER LOG)
OWN SHIP'S COURSE (FROM GYRO COMPASS)
MANUAL INPUTS (WIND DIRECTION AND SPEED, I.V.)
GUN DIRECTOR
5" 38-CALIBER GUN MOUNT
LEVEL & CROSSLEVEL
DIRECTOR TRAIN
TARGET POSITION AND SPOTS
GENERATED RATES
GUN ORDERS: SIGHT SETTING; FUZE SETTING; AND PARALLAX
STABLE ELEMENT
COMPUTER

Figure 7–27.—Data flow in Mk 37 system.

The computer is at the heart of the system. From the director, target elevation, target bearing, and range and spotting data (corrections based on observation of gunfire) go into the computer. The pitometer log and gyrocompass supply own ship course and speed. Some factors, like target course and speed, may be telephoned from the director and cranked into the computer by its crew. Other factors cranked in are wind data and initial velocity (I.V.). At the right of the computer you see its output to the gun mount: gun orders (elevation and train), fuze setting, sight setting, and unit parallax correction. The computer also puts director train into the stable element, which determines level and crosslevel angle, sending these values back to the computer.

Note also the line from computer to director, labeled "GENERATED RATES." These rates include generated elevation, generated train, and generated range. "Generated" means that the computer has worked these values out, as against "observed" values, which are what the director crew actually read off their dials. What is meant here is simply that the computer, having worked out a solution to the fire control problem, sends it aloft to drive the director. If the solution is correct, the director tracks the target on its own, and its crew doesn't have to crank it unless it goes off target.

Corrections for drift, air density, and some other factors are normally made by cams inside the computer, and therefore do not show in the diagram.

That, in a nutshell, gives you the essentials of a modern dual-purpose fire-control system.

MAIN-BATTERY SYSTEMS

There is no one "basic" main-battery fire-control system that can be considered the counterpart of the dual-purpose Mk 37. But all present main-battery systems are organized along more or less similar lines (fig. 7–28). The main elements are the director, the stable vertical, the rangekeeper, and the turret. The main outside data sources are the pitometer log and the gyro compass. Figure 7–28 also shows the flow of data in general; the specific data are very similar to the data that follow similar routes in the Mk 37 system.

Most of these elements are similar enough to their counterparts in the Mk 37 system to require no special explanation. The rangekeeper performs the functions of the computer, and the stable vertical those of the stable

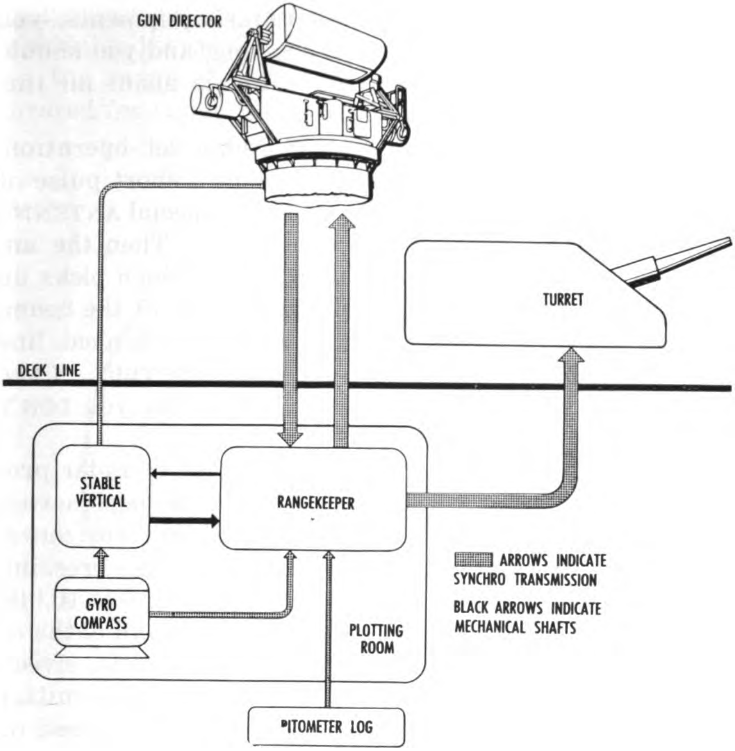


Figure 7–28.—Surface fire-control system. (Simplified schematic.)

element. The main difference between the stable vertical and the stable element is the way in which crosslevel and level are measured, and in certain provisions in the stable element (lacking in the stable vertical) for fire against air targets.

RADAR

You know that radar is a method for determining, by radio echoes, the presence of objects, their range, bearing, and elevation; for recognizing certain of their characteristics; and for making use of this information. Radar began as rather high-level stuff, but now there are radars right in gun mounts and turrets. Even though you're not expected to maintain radar equipments, you may have to work with them in spotting, and you should know what the general idea is. That is about all this section is intended to give you.

Here are the bare elements of radar set operation. A high-powered TRANSMITTER sends out a short pulse of intense high-frequency radiation from a special ANTENNA so that it issues more or less as a beam. Then the antenna is switched to a sensitive RECEIVER, which picks up radio echoes reflected by targets in the path of the beam. The echo shows up as a bright spot or a kinked line (BLIP or PIP) on the screen of a CATHODE-RAY TUBE. (The tube is like that of a television receiver, but you DON'T get a picture—only blips.)

All this happens pretty fast. In one type of radar presentation (type "A") a beam of electrons sweeps across the tube face at uniform speed in a straight horizontal line, then shuts off. Then a new beam begins crossing the screen again. This (in some radars) happens 10,000 times per second. Each traversal takes 100-millionths of a second (or 100 microseconds). Each time the sweep begins, a TIMER and KEYER cause the radar transmitter to send out its pulse, which moves out at the speed of light (186,000 miles per second or 328 yards per microsecond); then the antenna is switched to receiving until the next pulse.

Now, suppose there is a target at 1,640 yards. Traveling at 328 yards per microsecond, the radar pulse hits it in 5 microseconds. The energy reflected by the target bounces 1,640 yards back to the ship in another 5 microseconds. The radar antenna (now switched to the radar receiver) picks it up; the receiver converts it to an impulse to the cathode-ray screen.

But during this 10-microsecond interval, the electron beam has moved part of the way across the tube face. The reflected echo jogs it up for an instant as it continues to move its appointed way across the tube. That's the blip.

Because of the electron beam's uniform speed across the tube, the position of the blip is exactly proportional to the range of the target, and the screen can be calibrated for range as shown in figure 7–29.

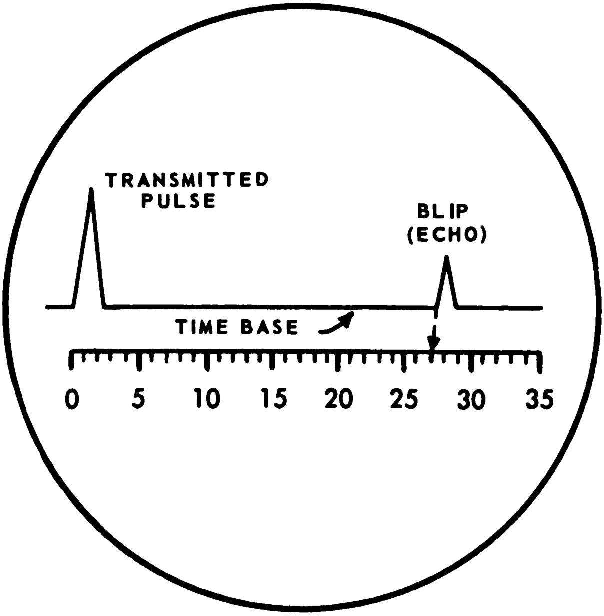


Figure 7–29.—Type "A" radar presentation.

Type "A" presentation is only one of several. Another common one is the PLAN POSITION INDICATOR, or PPI-scope. In the PPI, the antenna is mounted above the ship's structure. As it revolves continuously its beam scans the surrounding area. The cathode-ray screen shows a "radar map" of the area. The antenna is at the center of the map, and the path of the radar pulses shows as a glowing line revolving about the center as the antenna revolves. Figure 7–30 shows, on the left, a photograph of an actual PPI presentation; on the right is diagrammed the way in which range and bearing can be read from it. Targets and other features show as spots on the screen. The inside of the tube face is coated with fluorescent material so that the spots persist as the beam's bright line revolves.

Especially important in fire-control radar are the B-scope and the T&E-scope (fig. 7–30B and C, respectively). The B-scope provides a rectangular presentation of a small segment of the area, with range indicated vertically and bearing horizontally. The T&E-scope presents a view of a plane perpendicular to the antenna axis, with bearing indicated horizontally and elevation vertically.

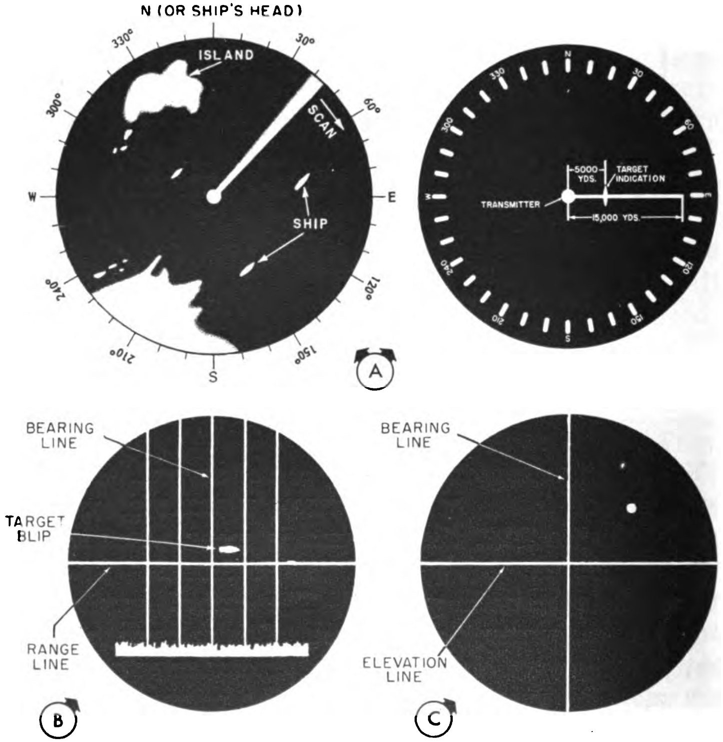


Figure 7–30.—Other types of radar presentation. A. PPI-Scopes. B. B-Scope. C. T&E-Scope

This may sound complicated, but if you look again you'll see that this amounts to a "radar-eye" view of what you would see through a gun sight telescope.

There are two main kinds of radar equipment aboard ship—SEARCH RADAR and FIRE-CONTROL RADAR. Most search radars have extreme range, but only fair precision. They can give approximate data on distant targets; they're also used in navigation and control of friendly aircraft. Fire-control radars, on the other hand, determine range, bearing, and elevation of a target with great precision for effective gunfire. They must also have good target resolution; that is, they must be able to distinguish between blips which are very close together, to permit accurate pointing and training, and spotting of splashes.

Surface fire-control radar is used with surface main batteries (on CL's, CA's, and BB's) to measure range and bearing only. When on target, in B-scope presentation, the vertical line in the center of the scope bisects the blip. Range is measured by shifting the movable horizontal range line with a knob control till it's tangent to the bottom of the blip; range then appears on a counter.

AA fire-control radar, besides supplying range and bearing, must also furnish target elevation. Range is normally read from an A-scope. For bearing and elevation, the radars employ either SCANNING or LOBE-SWITCHING.

In scanning, the radar beam is rotated in a conical pattern about the antenna axis, and presented by T&E-scope. The antenna is trained and elevated until the target blip appears exactly in the center of the scope.

In lobe-switching, the beam is transmitted "right-down-left-up" around the antenna axis. The right and left beams cause two blips to appear on the trainer's A-type scope, while the down and up beams cause blips on the pointer's (elevation) A-scope. When the two blips on the scope are of the same height, the antenna axis is on the target in train or elevation.

A radar may also be GATED on a target. That is, the target blip is picked up in a certain portion of the electron beam's scan (called the GATE), and the radar will automatically track it until it goes out of range or the radar is intentionally shifted. On some older radars, the process is not completely automatic, and it's called AIDED TRACKING; in new equipments it's completely automatic.

COMMUNICATIONS

Successful fire control depends on successful communications between widely separated points under conditions of intense noise and vibration, and in spite of casualties in both men and equipment. It's a difficult problem.

Some communication units (synchros, for instance) require no human assistance. But we also need both voice communication and audible and visible signals originated by the crew to fight the ship. That's what this section is about.

Sound-Powered Telephones

Years ago, the word was transmitted by lung power, either unaided or with the help of megaphones or voice tubes (which are still used). Then came telephones.

The Navy's first telephones were battery powered. But phones have a serious drawback: without the batteries, they can't work. This was made painfully clear on 7 December 1941. Aboard the *West Virginia* at Pearl Harbor the First Lieutenant couldn't contact his repair parties over the battery-powered telephone system. The batteries had been knocked out.

So today the battle interior communications system in every ship is built around the SOUND-POWERED TELEPHONE. There are no batteries. When you talk into the phone, you supply the sound energy that makes the system work.

You are by now familiar with the two main types of sound-powered phones—the HEADSET and the HANDSET.

When the headset is plugged in, its earphones are on the line; when you talk, you push the button on the transmitter. To listen or transmit with the handset, you push the button on the bar.

You should by now have studied and practiced the correct techniques of plugging in, testing, clear talking, circuit discipline, and securing sound-powered phones. To review them, see the *Telephone Talker's Manual,* NavPers 14005, which also explains briefly how the phones work.

When phone stations are not actually manned, there must be some way to signal them that they are being called. This is done by a CALL-BELL circuit that parallels the sound-powered phone circuit. Most such circuits use MAGNETO RINGERS, rather than battery power.

Now let's see how the sound-powered phone system is organized for actual use aboard ship.

Battle (sound-powered) telephones are set up as groups (circuits) of connected stations, rather than as individual stations. (You can connect individual stations to others, but this is not usual.) When you plug in, you are automatically connected with all the other manned stations on your circuit. Circuits are in turn organized into SYSTEMS. The three systems of battle telephone circuits are the PRIMARY, the AUXILIARY, and the SUPPLEMENTARY.

Each circuit within these systems is designated by a symbol. The symbols are intended to be uniform on all U. S. naval vessels; that is, each symbol refers always to the same circuit or type of circuit, no matter what ship it is on. Actually, there are two systems—an old one and a new. They differ in detail, but are basically similar. The examples given in this chapter are from the new system.

PRIMARY CIRCUITS are the main channels of communication for controlling armament and maneuvering the ship. Primary circuit symbols consist of a number, two letters, and another number—for example, 2JQ3. Let's briefly take up the elements of the symbols. The first number indicates the battery, as follows:

1. Turret (main-battery) circuits
2. Dual-purpose (secondary) battery circuits
3. Heavy machine gun circuits
4. Light machine gun circuits
5. Torpedo battery circuits
6. Depth-charge battery circuits
7. Antisubmarine projector battery circuits
8. Rocket battery circuits
9. Guided-missile battery circuits.

The letter indicates the function of the circuit:

JB—Spotters
JC—Control
JK—Fuze setters
JN—Illumination control
JP—Group control
JQ—Sight setters
JW—Range control

The last number in the symbol indicates the corresponding group, mount, or turret number. Circuit 2JQ3, then, is the sight setters' circuit for group 3 in the dual-purpose battery.

All primary circuits for the ship's armament can be interconnected on switchboards in the plotting rooms, as well as by other control switches. (By and large, other sound-powered phone circuits have no switchboards, though some interconnecting can be done by control switches at various stations.) These facilities are important for tying circuits together, for transferring control from one point to another, for providing emergency communications, and for isolating circuits or individual stations (in case of casualty, for example). You're not concerned with how the switchboards are operated—that's up to the plotting room crew.

Primary-circuit phone connections are automatically switched by the plotting-room crew whenever control is shifted from one station to another. For example, suppose that the gunnery officer on a cruiser orders the forward main battery to be put under the control of the dual-purpose battery director. This requires not only switching the control and indicator circuits of the turret, but also connecting part of the main-battery phone circuit (1JP) with the forward secondary battery phone circuit (2JP). This is done by making cross connections on the switchboard. The crew down in the plotting room takes care of the plugging and switching involved; they also take care of switching other affected circuits (fuze setters, to circuit 2JK; sightsetters, to circuit 2JQ) as required.

But switching is not a monopoly of the switchboard. The mount captain or control officer can be throwing a switch disconnect his battle-phone control circuits from plot and tie them all together for local control. Other switches make possible still other connections.

The AUXILIARY battle-telephone system is a standby which parallels the more important primary circuits and is intended for use in case of casualty to them. It has no switchboards. Each auxiliary circuit is designated by the letter X, followed by the symbol of the circuit for which it is a substitute. Thus, the main-battery control auxiliary circuit would be given the symbol X1JC. Since the auxiliary circuit is not continuously manned like the primary, it is generally equipped with handsets rather than headsets.

SUPPLEMENTARY CIRCUITS are those not important enough to be in the primary system. They are numbered X (number) J. In turrets, the first digit corresponds to the number of the turret—for example, turret 2 would have circuits numbered X201J, X202J, and so on.

In mounts and turrets, supplementary circuits are mostly concerned with the ammunition supply system. Thus, in enclosed twin mounts, X17J connects the top and bottom of the lower ammunition hoist. Turrets have more supplementary circuits. The *Salem* class 8-inch turret, for example, has nine, one of them connecting the turret officer with gun-positioning and sightsetting stations, and with the safety watch; others interconnecting the ammunition supply system with the gun captains and turret officer.

Supplementary battle telephone circuits have no switchboards, but at gun captains' and mount captains' stations are switches that can interconnect different supplementary circuits, or tie them in with primary control circuits.

Remember These!

1. The crewman assigned to a phone station is the one PRIMARILY RESPONSIBLE for seeing that his phones are at the station and in working order. It's up to him to see that defective phones are repaired by the I. C. electrician's shop.
2. When you're on the job as gun or mount captain, the entire gun or mount is your responsibility. A lot depends on how your men handle their phones, how they talk into them, and how well they maintain circuit discipline. And, in turn, their efficiency at the phones will be influenced by the example you set them. The best way to keep them on the ball is to stay on the ball yourself.

Ship's Service Telephone

The ship's service or automatic dial telephone system (circuit J) is similar to the conventional dial systems you find ashore. It is electrically powered, and has a central switchboard and dial apparatus for making connections between stations. When you call a station that is in use, you get the same kind of busy signal that you would get in conventional telephone systems ashore. An EXECUTIVE RIGHT-OF-WAY arrangement makes it possible to break into a conversation, but this is possible only for a few stations, like the bridge and quarterdeck.

Because in general only two stations at a time can be on one circuit, and because the system is vulnerable to power failure, the ship's service telephone system is not for use under battle conditions. However, you will find one dial station on larger mounts, and usually two on turrets.

Shipboard Announcing System

The shipboard announcing system is a network of public-address systems (MC circuits), using electrically powered amplifiers, with transmitters (microphones) and reproducers (loudspeakers) spotted all over the ship. The main system for the ship is the 1MC or GENERAL ANNOUNCING SYSTEM, operated by the OOD, which serves all parts of the ship. Other MC systems serve various departments, or have special purposes. Those of special interest to you as a Gunner's Mate are the 17MC, on dual-purpose mounts, and the 11MC, 12MC, and 13MC, respectively, on turrets 1, 2, and 3 on ships with main-battery turrets. Machine-gun mounts are not served by any MC system besides the 1MC for the ship as a whole.

The 17MC system is under the control of the dual-purpose director officers; the turret MC systems are controlled by the turret officer in each turret. These systems can also be tied together and to 1MC. They give verbal orders and information, transmit general alarm and chemical attack signals, and relay salvo and cease-firing signals.

The 17MC system is one-way, but in the turret systems, most of the reproducers can be used as transmitters for two-way communication.

Signal Systems

Besides these voice communication systems, modern naval ships are equipped with several systems of audible signals.

1. *Safety Regulations* of the United States Navy require that before any turret or enclosed mount is moved in train, a warning signal must be sounded on the TRAIN WARNING SIGNAL circuit (TW), except during GQ. The TW circuit is independent of all other IC circuits. It consists of a pushbutton control switch, wiring, power supply, and bells outside the turret or mount.

2. The call signal system (circuit E) parallels supplementary battle telephone circuits and voice tubes. It consists of interconnected power-supply units or magnetos, selector switches, and buzzers or bells.
3. The order to cease fire is normally given by sounding a gong. Cease-firing signal circuits are:

Main battery	1U
Dual-purpose battery	2U
Heavy machine gun battery	4U
Light machine gun battery	5U
Rocket battery	9U
Sector control	45U

The (45U) circuit is a combination of 4U and 5U, but the armament is divided into groups by sectors rather than by sizes of weapon. Thus all AA fire from both heavy and light machine guns in any sector can be controlled by one station. This circuit can also be interconnected with the headsets of the gun crews, so that they hear the cease-fire in their phones as well as on reproducers at the mounts. Dual-purpose mounts hear it through the 17MC system.

4. The salvo signal is a loud buzz. In secondary-battery mounts it is transmitted by the 17MC system. In turrets, salvo signal buzzers are installed on the gun deck level. The circuit is coded as 1VB in main-battery and 2VB in secondary-battery installations.
5. The intraturret emergency alarm is an independent circuit used to warn of danger or serious casualty in the turret. It consists of a number of small electric sirens that can be set into operation from any of several stations in the turret. The turret officer's booth has a switch for silencing the sirens.

SPOTTING

Most likely you already have some idea of what spotting is. In that case you also know that it's a fairly difficult art, and that fire-control and gunnery officers spend a good deal of time on study and practice to attain proficiency in it.

But it's also true that as a GM2 you can't leave it entirely to the higher echelons. True, when your entire battery is in automatic and the fire control system is working right, spotting isn't one of your worries. Yet your mount or turret isn't always in automatic, and the fire-control system can be knocked out (by real or simulated casualties). What then?

Then, if you're a mount or turret captain, you become a spotter—you can't leave it all to the higher echelons. So let's take a closer look at spotting.

With smaller weapons, spotting is a function every gunner performs on his own; the man who both aims and fires his gun does his own spotting. On mounts with more elaborate sights, where more than one man positions the gun in train and elevation, fires, sets fuzes, and introduces sight corrections, the spotter is important—even in 20-mm mounts with lead computing sights, where a rangesetter spots for the gunner. But we shall, in this section, be more concerned with larger mounts, like the 5".

Definitions

Radar spotting requires pretty thorough grounding in "blipology" and methods of radar presentation. So we'll take up optical spotting only. Let's discuss some definitions. Some of these are illustrated in figure 7–9.

1. A salvo consists of two or more shots fired at the same target, at the same time, on the same signal.
2. POINT OF IMPACT is the place where each shot hits.
3. MEAN POINT OF IMPACT (MPI) of a salvo is the point at the geometrical center of the points of impact of all the shots of a salvo (except wild shots).
4. WILD SHOT is a point of impact abnormally far from MPI.
5. LINE OF FIRE is the true bearing of the target from the battery at the instant a shot or salvo is fired.

6. PATTERN is the area covered by the points of impact of a salvo (except wild shots). PATTERN IN RANGE is the distance, measured parallel to the line of fire, between the point of impact nearest to the battery and the one farthest away. PATTERN IN DEFLECTION is the distance, measured at right angles to the line of fire, between the points of impact at the extreme right and left of the pattern (fig. 7–9).
7. DISPERSION of a shot is its distance from MPI. When you average the dispersions in a salvo you have MEAN DISPERSION.
8. BRACKETING describes two successive salvos falling so that the target is between them. Bracketing may occur in either range or deflection.
9. STRADDLING describes the fall of one salvo so that the target is in the midst of the pattern.

The Spotter's Duties

The spotter's duties for the main battery are set up in the ship's battle bill and fleet doctrinal publications. You're not likely to serve as the ship's spotter, but in many ways spotting for a 3-inch or 5-inch mount in local control is more or less a miniature of his job. His main duty is to correct gun laying errors so as to get his gun fire to hit the target, but he has others:

1. Search for and locate the enemy.
2. Describe enemy forces (number of ships, bearing, etc.).
3. Estimate all values for the initial rangekeeper setup (enemy speed, target angle, etc.).
4. Notify Plot and Control of changes in target angle, etc.
5. Keep Conn and Control informed of the tactical situation.

When you're spotting for your own mount or sector, you'll be doing No. 1 at relatively short range, and you won't have much occasion to do No. 2 unless you're asked for the information. You'll be doing a lot of No. 3 and

No. 4, but you probably won't have a rangekeeper handy and your information will be for the benefit of your own mount. That's why it's important for you to become expert at making quick, accurate range, bearing, and target speed estimates—and that takes practice. As for No. 5, you will more likely GET tactical information from your control officer.

To estimate target angle of surface targets at any considerable range, you should know the structural details of likely targets. Study the scale models and silhouettes provided on your ship for target angle estimation as well as recognition. Estimation of air target speed requires experience—though it helps to know performance characteristics of typical enemy aircraft. The same goes for surface targets. These also furnish cues to speed in the form of smoke from the stacks, bow waves, and wake. In estimating range of any target, you should have a good idea of the ACTUAL size of the target. Then, if you can find the size in mils, it isn't hard to make a good estimate of range.

Now let's get back to the spotter's main duty—seeing that the battery or gun mount is properly laid for hits. First you estimate, on the basis of observing the target, the range, bearing, and target elevation. Then you order a salvo fired at settings for these values, and observe how close the shots fall. On the basis of your estimates of error, you order corrections or SPOTS in range and deflection. This you do using standardized expressions, as follows:

1. SURFACE TARGETS (afloat). For these, you spot only range and deflection, usually in that order. (If the first salvo is far off in deflection, you may have to spot in deflection first, so that you can see if the splashes of your next salvo are over or short, but ordinarily you should spot range first.) For range correction you say "ADD (or DROP)........................ YARDS." For deflection correction you say

"RIGHT (or LEFT)........................MILS." Where no correction is necessary, you say "NO CHANGE."

NOTE: Always give spots in the SAME ORDER—first range, then deflection. If you want to order a spot in deflection and none in range, say NO CHANGE for range, then give your deflection spot. When you are on target, you order RAPID FIRE or whatever else is called for by the requirements of standing orders or fleet doctrine.

2. AIR TARGETS. For air targets you make corrections in three dimensions, and you need them fast. Even experienced men have a hard time estimating errors rapidly in three dimensions. AA spotting is therefore not attempted very often, and then mostly to compensate for serious constant system errors. The proper terminology for AA spotting is:

   Range correction—ADD or DROP, in yards.

   Height-of-burst correction—UP or DOWN, in minutes.

   Deflection correction—RIGHT or LEFT, in mils.

3. SHORE BOMBARDMENT. In shore bombardment, as in AA, spots in three dimensions are often necessary. The terms are the same as those mentioned, but the units are different. When naval guns support landing operations, joint forces are involved. The Navy, Army, and Air Force have a standardized spotting terminology with all corrections in yards.

Methods of Spotting

Methods of spotting used aboard ship are prescribed in fleet technical publications, and you must conform to them. But it may be helpful to review in general the important spotting methods:

The DIRECT method is to order a spot equal to the estimated correction. This method is used by the main battery spotter at medium ranges, or by observers in aircraft to estimate range spots. Otherwise its main use is in radar spotting.

BRACKET-AND-HALVING is used at long ranges by the main battery when no radar or aircraft spotting is available. When the splashes are in line with the target, the target is bracketed by firing one salvo short and then another that is sure to be over. The next spot halves the difference between the short and over salvos. Halving continues until the target is straddled. Then the battery shifts to continuous or rapid salvo fire.

The LADDER method is to open fire short, and increase range in steps larger than pattern size. When the target is bracketed, the range spot is halved and further adjusted until the target is straddled. This method is used where ranging is difficult and visibility is poor.

The BARRAGE method is to place a zone of fire short or over the target, so that the target will move into the zone as it maintains its course and speed. The barrage zone is shifted to keep the target in it. This method can be used by AA and dual-purpose batteries against fast-moving targets.

The TRACER method of control consists of spotting shots by noting the error as the tracer passes the target. It is used chiefly in spotting machine gun fire. At longer ranges, tracers are not much help to the spotter, because it's hard to keep them in sight or to judge when they pass the target. Under certain light conditions the tracers can't be seen clearly, and should not be relied upon except for short-range firing.

As you've probably noticed, spotting techniques for surface targets are much better developed than for air targets. As the AA problem has become more important, radar has been developed and refined. In the newest fire-control systems (for example, the Mk 56) radar has become the heart of the system; even optical tracking (let alone spotting) has become secondary in importance.

However, visual spotting of air targets is by no means a lost art. The ring sight is a great help. Naturally, it isn't as efficient as a lead computing sight, but it's still provided for emergency use on open mounts and at the mount captain's station on enclosed 5'' mounts. With practice it can be as effective as it was before the improved sights were introduced into the Fleet.

To correct your fire visually when using VT-fuzed ammunition, one technique is to fire every third or fourth round using time-fuzed AA projectiles, and spot by using air bursts. There are other wrinkles, too, in spotting AA fire. To pick these up, and in fact to keep up to date on the whole subject of spotting, keep abreast of the fleet technical publications on your ship.

TYPES OF CONTROL

By way of summary, let's see how the gun fire-control system works as part of the ship's armament. This, again, is a field in which even specialists must spend a great deal of time and effort before they become expert.

On every warship there are several possible types of armament control. The preferred one is PRIMARY CONTROL; all the others are SECONDARY. On all combat ships the size of a DE or larger, the primary setup provides for remote control from a director.

Here are the methods of secondary control:

1. STAND-BY. This is control by the stand-by plotting room alone. Ships with two plotting rooms designate one as STAND-BY, and the other as MAIN PLOT. If main plot is knocked out, or the battery has to handle several targets, stand-by plot (which generally is in continuous operation along with main plot, ready to take over) picks up operations.
2. AUXILIARY. This means use of an auxiliary computer in fire control. Ships with but one plotting room use this method when fire by one battery at more than one target is necessary, or when plot is knocked out.
3. INDICATING. This means matching pointers manually at the gun mount to follow gun orders. This method would be used where the remote control system is out, but data transmission is still intact.

4. TELESCOPE. Here the director and computer are still functioning. but the mount can receive only range (or sight angle), deflection, and fuze setting. In this and the following two types of control, the pointer and trainer keep their sights on target while the sightsetter cranks in sight angle and deflection, and the fuze setter is reset manually. Actual firing may still be remotely controlled.
5. EMERGENCY. This is like telescope control, but without the director. Sight angle, deflection, and fuze setting are transmitted from one of the mounts or turrets in the battery acting as control station.
6. LOCAL. Here sight angle, deflection, and fuze setting are all determined at the mount or turret, all firing is locally controlled, and gun pointing and training are by telescope.

CONCLUSION

In this chapter and the preceding one you have been given a swift survey of the principles of fire control, of Navy fire-control equipment, and of how it is used with shipboard guns. In other chapters of this course and in later courses in this series you will take up in further detail some of the fire-control equipment that you work with on gun mounts.

QUIZ

In each of the following eleven questions, select the one BEST answer.

1. Which of the following types of sights has no reticle?
   a. Telescopic
   b. Peep-and-ring
   c. Lead-computing
   d. Prismatic

2. Which of the following best defines precession?
   a. The movement of a gyro wheel about its axis of rotation
   b. The resistance offered by a gyro to shift of its axis
   c. The tilt of a gyro at right angles to a force that shifts its axis
   d. The tendency of a gyro to maintain its attitude in space

3. In a lead-computing sight the precession of the gyro is
   a. proportional to the rate of turn of the sight
   b. equal to the gyro spin
   c. inversely proportional to target speed in knots
   d. equal to superelevation angle

4. The action of the gyro and superelevation lever arm in the Mk 20 lead-computing sight causes the line of sight to shift by moving the
   a. reticle
   b. collimating lens
   c. mirror
   d. target image

5. Which of the following directors does NOT transmit gun order?
   a. Mk 37
   b. Mk 51
   c. Mk 52
   d. Mk 63

6. Which of the following features of the Mk 37 director is found also in all directors with lead-computing sights?
   a. Power drive
   b. Telescopic optics
   c. Optical rangefinder
   d. Synchro transmitters

7. Horizontal parallax in general increases with
   a. target range
   b. target elevation
   c. height of director above the deck
   d. distance between director and gun mount

8. A synchro repeater is a
   a. synchro receiver equipped with dial
   b. synchro control transformer equipped with dial
   c. synchro transmitter
   d. dial showing corrected response

9. In the 40-mm mount servo system, the error signal is the
   a. gun order signal from the director
   b. difference between gun order signal and gun position
   c. present position of the gun
   d. director position plus gun laying corrections

10. Level is always measured parallel to
   a. crosslevel
   b. the line of sight
   c. the stable element
   d. roll and pitch

11. Which of the following is an input to the stable element?
   a. Target bearing
   b. Level
   c. Crosslevel
   d. Target elevation

This set of problems tests how well you remember the operation of a typical fire-control system. Column B consists of a list of possibilities for the flow of data, orders, or corrections, which are listed in column A. Select the item in column B that includes the *source* of each of the items in column A. There is no limit to the number of times you may use an item in column B.

Column A

12. Gun elevation order
13. Horizontal parallax
14. Sight deflection
15. Target elevation
16. Crosslevel
17. Sight angle
18. Gun train order
19. Fuze setting order
20. Level angle
21. Vertical parallax
22. Generated range
23. Director train as transmitted from computer

Column B

(a) Director to computer
(b) Computer to gun mount
(c) Computer to director
(d) Computer to stable element
(e) Stable element to computer

In the following questions, select the one BEST answer.

24. Which of the following radar presentation methods resembles a map with the radar antenna at its center?

a. Type A
b. Type B
c. T&E-scope
d. PPI-scope

25. Primary battle telephone circuits may best be defined as
a. the main communications channels for maneuvering the ship and controlling armament
b. the communications channels that connect the ship's batteries and fire control
c. those used by the ship's captain in directing the ship's operation
d. those that are manned by personnel wearing headsets

26. Spots are
a. the splashes produced by the fall of projectiles into the sea
b. corrections ordered on the basis of observed fire
c. hits on the target correctly predicted by the computer or rangekeeper
d. the dimensions of the pattern in range and deflection

27. In which of the following types of control does a gun mount or turret function as control station for the battery?
a. Stand-by
b. Local
c. Emergency
d. Auxiliary

CHAPTER 8

GUN MOUNTS—20-MM TO 5-INCH

INTRODUCTION

You already know that a modern gun mount comprises the entire system of gun-supporting parts, elevating and training mechanisms, sight mechanisms, and part of the recoil and counterrecoil equipment. In this chapter we'll discuss the important types of gun mounts the Navy uses today for guns 20-mm to 5-inch caliber. (The simple types of mount used for caliber .30 and .50 automatic weapons are taken up briefly in the chapter on small arms; turrets (for guns larger than 5-inch) are not taken up in this course.)

We'll take up in some detail all the main features of these mounts, as mentioned above, except for recoil and counterrecoil equipment, which will have a later chapter to themselves. We'll also review briefly safety precautions, casualty procedures, and crew stations and duties for each type, and list references you should study for further details. Let's begin with the 20-mm mount.

20-MM MOUNTS

The main function of the 20-mm mount is to support the gun at the height most convenient to the gunner, and to permit the gun to swing freely in elevation and train. There is no elevating or training mechanism. The mount contains no ammunition supply facilities; the gun is, as you know, fed by a detachable 60-round drum magazine mounted on its breech casing.

20-mm Mount Types and Construction

The 20-mm mount is, compared to larger mounts, a relatively uncomplicated affair. During World War II, there were three types—the FIXED, the MECHANICAL, and the HYDRAULIC. The mechanical and hydraulic 20-mm mounts, respectively, incorporated mechanical and hydraulic devices to raise and lower the gun trunnions and make it easier for the gunner to shift rapidly to extreme angles of elevation and depression. In today's active fleet, however, the only types you can expect to come across are the fixed single-mount Mk 10 and its mods, and the fixed twin mounts Mk 20 and Mk 24 and their mods.

The fixed single mount (fig. 8–1A) is simply a three-legged stand or PEDESTAL supporting a pivoted CARRIAGE which can move freely in train. The trunnions of the CRADLE, into which fits the gun itself, are supported in bearings in the two arms of the carriage. Thus the carriage can move in train, and the cradle and gun can pivot on the trunnions for movement in elevation. The gun can be quickly mounted in or detached from the cradle.

The twin mounts are very similar in general (fig. 8–1B). One cradle supports both guns. The left gun's magazine (with zigzag markings) is of opposite hand from that of the single (or right-hand gun of the twin).

In present single and twin 20-mm gun mounts there is no provision for power drive. The gunner himself aims in train and elevation. Though the 20-mm gun and mount are by no means as massive as their larger brothers, the total weight, in a fully equipped and loaded twin mount, of the parts that move in elevation and train, may come to a quarter ton. To keep the task of moving this mass within manageable limits, SPIRAL SPRINGS around the

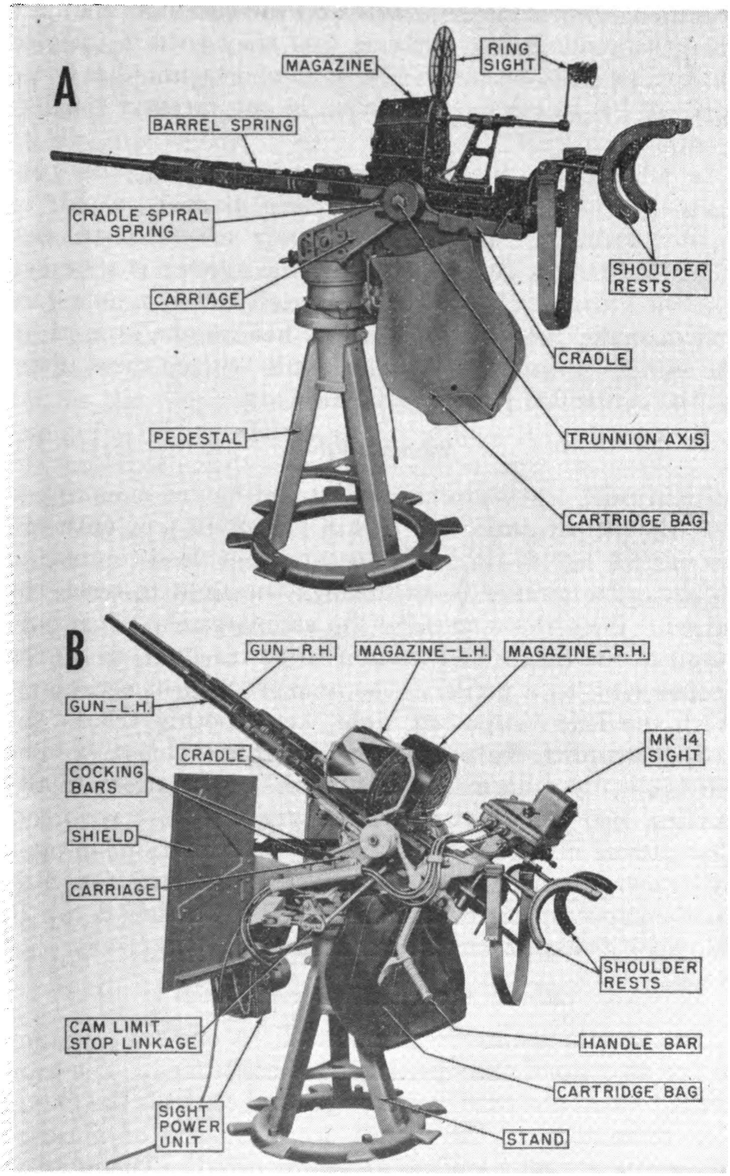


Figure 8–1.—20-mm fixed mounts.

trunnions, linked to the cradle and the carriage, counterbalance the elevating parts so that they remain in good balance at all elevations. (Twin 20-mm mounts have two springs; in single mounts there is one, around the left trunion.)

In addition to the counterbalancing spring, the gunner's task is made easier by a special harness, a pair of padded SHOULDER RESTS, and a pair of HANDLE BARS. When the mount goes into action, the gunner is strapped into the harness. By applying himself to the handle bars and shoulder rests, he can throw his weight around on the gun to maneuver it. The gun's trigger mechanism can be controlled from the handle bars.

20-mm Sights

In present installations, the 20-mm mount is equipped either with peep-and-ring sights (fig. 8–1A) or with Mk 14 (as in fig. 8–1B), Mk 20, or other lead-computing sights. The gunner looks through the sight to track the target. With the ring sight, he estimates the range and speed of the target and leads it as he tracks it, using the proper ring as a guide to the amount of lead necessary. With the lead-computing sight, he smoothly tracks the target, keeping the reticle on target at all times. The built-in computing mechanism of the sight automatically applies lead and superelevation angle values required. The gunner also uses the trajectory information supplied by tracer ammunition in correcting his fire for hits. Lead-computing sights are discussed in further detail in this book's chapter on fire control.

20-mm Crew Stations and Duties

The 20-mm mount is substantially a one-man weapon so far as control and operation are concerned. The gunner sights on and tracks the target and controls the firing. The remainder of the mount crew consists of a range setter and as many loaders as are required. (The number depends on whether the mount is a twin or a single, and its distance from the ammunition locker.) The gunner is in charge of the crew, and has the general responsibilities of acting as gun captain, directing operations, and enforcing safety precautions. He is responsible for seeing that equipment is on hand and tools are available for repair of casualties.

The range setter receives or estimates the range data, sets the range pointer on the lead-computing sight, and introduces deflection or elevation spots as required.

The first loader stands at the gun position with a magazine on his left shoulder. He acts on two commands—"HALF LOAD!" and "LOAD!" At HALF LOAD, he places the magazine on the gun, tilted forward so that the guide lugs on the magazine engage the receiving slots on the breech casing. At LOAD he plants the rear of the magazine smartly downward so that the rear lug engages the magazine interlock catch. He gives the magazine a shake to see that it is securely seated. And during fire he watches the ammunition supply, keeping an eye on the slots in the magazine's rear face which show the cartridges in the feed. He must be ready to replace an empty magazine immediately.

20-mm Safety Precautions and Casualty Procedures

In the preceding course in this series you learned in detail about the functioning of the 20-mm gun and its maintenance. As a GM2 you are responsible for training battle station crews in the safety precautions and casualty procedures for the 20-mm mount. Let's briefly review them here:

1. In case of a casualty, only the men required to handle casualties should be permitted near the gun. Always be sure the gun is pointed in a SAFE direction.
2. Water must always be on hand to cool the gun off or receive an unexploded cartridge.
3. When removing hot barrels always keep the muzzle pointed seaward. The crew must stand clear.

4. When cooling the barrel in the water trough or "dip pot" at the gun mount, stand clear so that hot spray or steam doesn't burn you.
5. Before firing, check for "all clear" bore. Always take this precaution when replacing a hot or worn barrel with another.
6. Use the ejector rod with extreme care—preferably after the gun has been cooled with water.
7. When ejecting a live cartridge, first place a glove or rag in the breech casing to keep the projectile from falling into the bag.
8. An ejected live cartridge should be immediately placed in a pail of water or thrown overboard. Do NOT hold it in your hand for inspection! Douse it first and examine it later!
9. If a live projectile falls into the cartridge bag, remove it at once and take prescribed precautions.
10. In case of a misfire or stoppage:
    a. Assuming the gun is hot and has misfired, douse the gun liberally with water AT ONCE without waiting to determine the cause of malfunction.
    b. If no water is available, the breechblock should be withdrawn sufficiently (by partially cocking the gun) to establish that a round is in the barrel. If a round is in the barrel, the safest action to take is to close the breech, secure the gun, and stand clear.
    c. But suppose you're in action and it's necessary to resume service of the gun without waiting for the barrel to cool. Use the ejector tool IMMEDIATELY. Open the breech, insert the ejector tool in the muzzle, and drive the projectile, if any, out of the bore. If there is a loaded and fuzed projectile in the bore, and the gun can't be cooled for lack of water or time, you have about a minute and a half to remove the projectile. So move fast!

d. If you DO have an opportunity to wet down the barrel, remove it and dunk it in the dip pot without delay.

Misfire is one of the more common casualties, and a Gunner's Mate should know how to handle same and apply effective mechanical first aid if necessary. Know your gun. The OP on it is OP 911; OP 909 and OP 1439 are about the single and twin mounts, respectively.

40-MM MOUNTS

Through most of World War II and for some time thereafter, the 40-mm gun was the most important heavy machine gun in the United States Navy. Although it is now being displaced by the 3-inch mechanically loaded rapid-fire (RF) gun, you will still find it on many combat ships and auxiliary vessels.

40-mm Mount Types and Characteristics

There are four main types of 40-mm mounts, each differing chiefly in the number of guns carried or in the power drive. The Mk 1 is a twin mount; the Mk 2, a quadruple mount; the Mk 3 and M 3 are singles; and the Mk 4 is a quad with different power drive from the Mk 2. Each of these marks exists in one or more mods.

All 40-mm mounts are of the open deck-emplaced base-ring type, capable of at least 720° train. Elevation limits are +90° and —15°. Ammunition is stored in ready racks in the bulkhead around the mount, handy to the gun crew. The guns of the twin and quad mounts are water-cooled; each gun has an independent cooling system with its own motor-driven pump. The gun on the single mount is air-cooled. Recoil is controlled by a hydraulic brake. The twins and quads have an external counterrecoil spring; in singles it is concealed.

To become acquainted with some of the features common to all 40-mm mounts, let's glance at the twin (fig. 8–2). The guns are arranged as a twin assembly mounted on a common carriage with a common elevating arc.

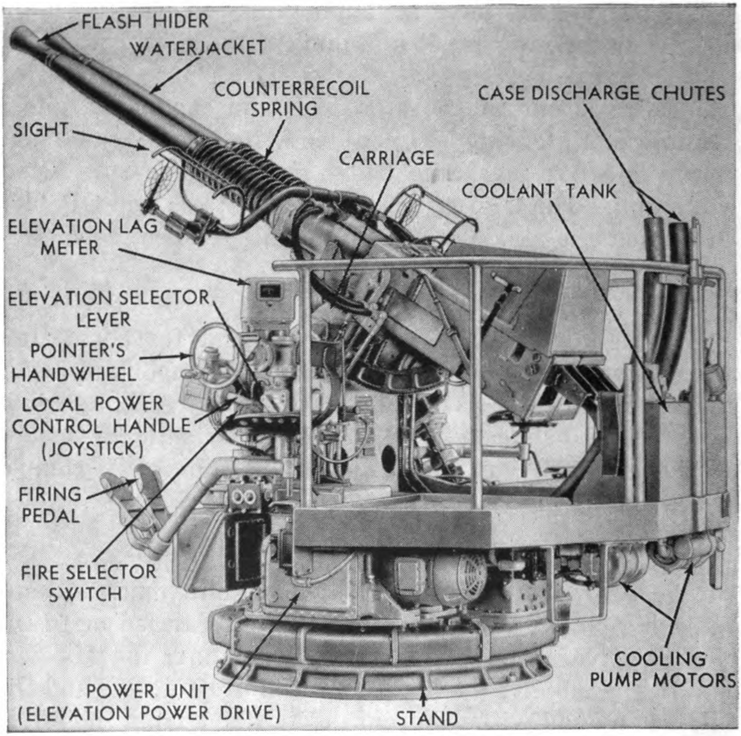


Figure 8–2.—40-mm twin mount Mk 1—pointer's side.

Both guns elevate, depress, and train as a unit with the axes of their bores always parallel. On the right side of the mount is the trainer's seat, footrest, handwheels, train power drive with its controls, and the trainer's open sight. On the left is the pointer's station with footrest, seat, handwheel, elevation power drive with its controls, and pointer's open sight. At the pointer's station you will also find the FIRING PEDAL, the FIRE SELECTOR SWITCH, and the LOCAL POWER CONTROL HANDLE, commonly called the "joystick." (The old Mk 1 Mod 2 mount, with all-electric power drive, has no joystick.) On the front of the carriage are the FIRING MOTOR, the FIRING MECHAN-

ISM, and FIRING CUT-OUT MECHANISM. At the rear of the carriage are the CASE DISCHARGE CHUTES.

The quadruple mount consists of two twin carriages side by side, with the trunnion axes in alignment with all gun bore axes parallel and always in the same plane. At the right side of the right carriage are the trainer's station and the train power drive; at the left of the left carriage is the pointer's station and the elevation power drive. Each carriage has its own elevating arc and elevating gear train driven by the mount's one elevation power drive. Each carriage also has its own firing motor, firing mechanism, firing cut-out mechanism, and case discharge chutes.

Now let's examine more closely the main features of 40-mm twin and quad mounts—the ones in capital letters in the preceding paragraph on the twin mount. We'll begin with firing controls and linkage.

40-mm Firing

Firing of the 40-mm gun is controlled by a trigger mechanism in the slide, which releases the spring-operated rammer. As long as the firing plunger in the trunnion is pushed inward, the trigger mechanism of the gun will, in automatic fire, remain in firing position, and the gun will continue to fire as long as it is supplied with ammunition.

There are three ways to push the firing plunger inward:

1. The pointer can depress his firing pedal all the way (36°), mechanically operating the firing linkage to the trunnions so that they push the firing plungers home. When the pedal is released, the trigger mechanism moves automatically to stop-firing position, and firing ceases. This is called MANUAL FIRE.
2. Under normal circumstances, the firing linkage is actuated electrically. In LOCAL FIRE, the pointer depresses his firing pedal halfway (18°), closing a

switch which energizes a SOLENOID COIL. Releasing the pedal opens the switch and deenergizes the coil, and fire stops.

3. In DIRECTOR FIRE (also electrical), the pointer keeps his pedal down as for local fire, but a switch at the director controls fire. Either opening the switch at the director or releasing the firing pedal stops director fire.

Any of these methods of fire may be selected by setting a firing-selector switch at the pointer's station.

The little solenoid in the 40-mm firing mechanism doesn't directly operate the firing plunger. Instead, it

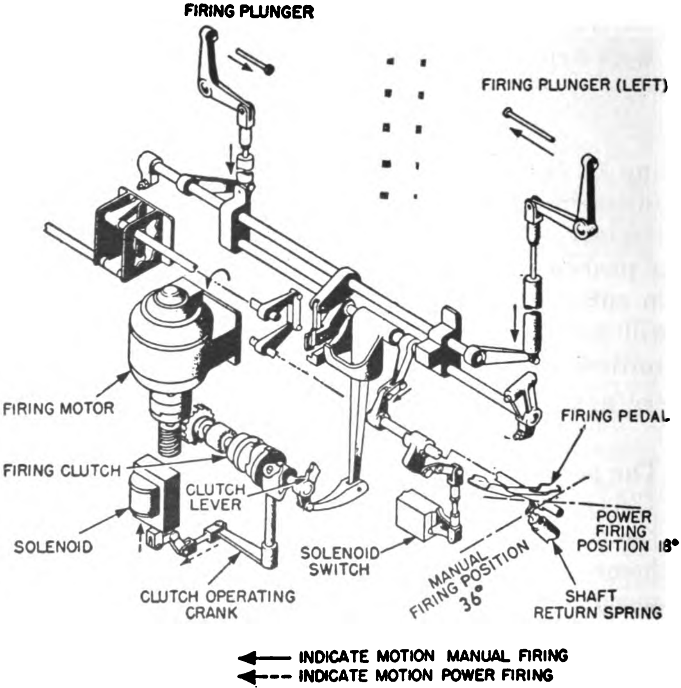


Figure 8–3.—40-mm quad mount. Schematic of firing mechanism. (Left pair of barrels only).

engages a FIRING CLUTCH which permits a 1/3-horsepower electric motor to move the firing linkage (fig. 8–3). When the solenoid is deenergized, the linkage returns to stop-fire position. The motor keeps running all the time that the mount is manned for action, and actuates the firing mechanism through a worm drive.

One feature of this firing mechanism that the figure does not show is the firing clutch action. When the solenoid causes the clutch to engage the firing linkage to the firing motor, the motor moves the driven part of the clutch and the clutch lever through one-quarter turn (90°). Then, in order to prevent the motor from stalling, the clutch disengages, permitting the motor to run without load. A latch in the clutch locks the linkage in firing position until the solenoid is deenergized; when that happens, the clutch and linkage return to their original (nonfiring) position.

The 40-mm mount has a cam-operated firing-stop device that prevents functioning of the mount firing mechanism when the gun is aimed at the ship's structure. Note that this device does NOT affect the functioning of firing mechanism components in the gun slide.

In both twin and quad mounts there is one firing motor, firing mechanism, and firing-stop mechanism for each pair of guns.

40-mm Ammunition Facilities

The 40-mm gun mechanism is designed to fire at a rate of approximately 140 shots per minute. A quad mount firing at this rate therefore puts some 560 projectiles into the air every minute. You can easily see that ammunition supply to 40-mm mounts requires special consideration by the ordnance designer.

Ammunition for immediate use in 40-mm gun mounts is kept in READY RACKS on the bulkhead surrounding the mount, as shown in figures 8–4 and 8–5. Ammunition supply for prolonged firing, however, comes from below decks in the MAGAZINE, where 40-mm ammunition is

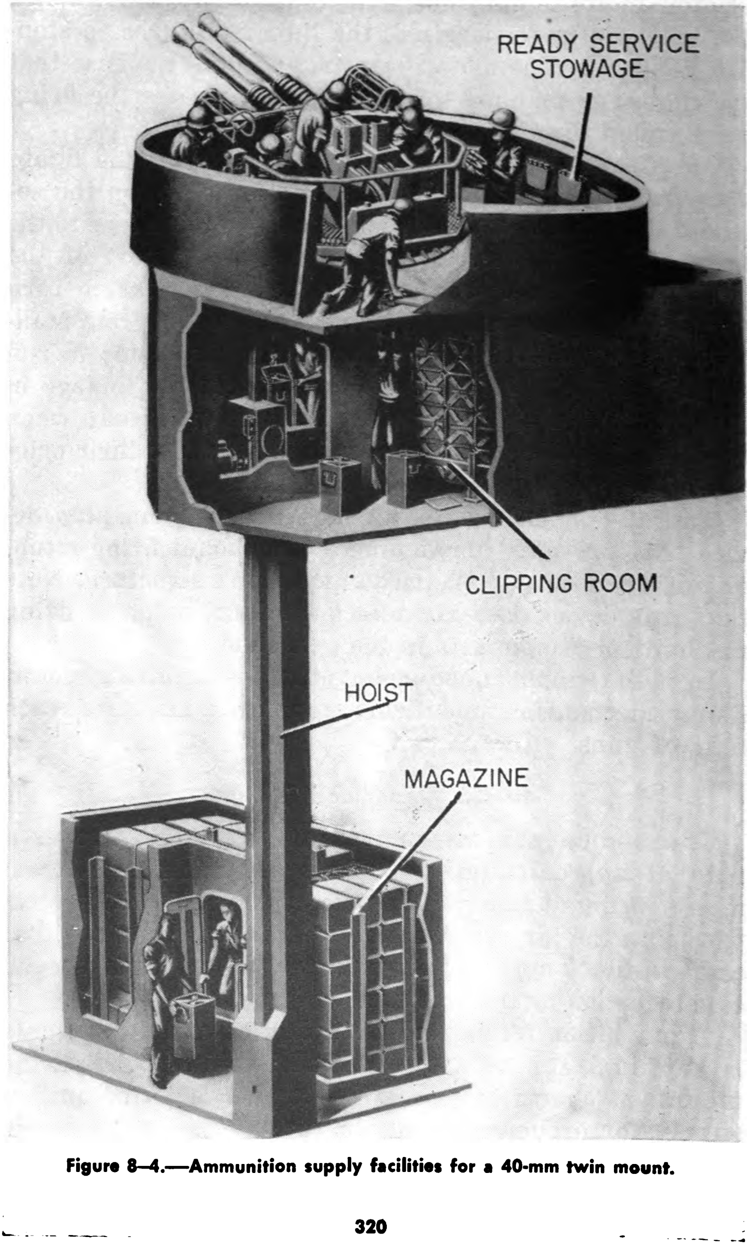


Figure 8–4.—Ammunition supply facilities for a 40-mm twin mount.

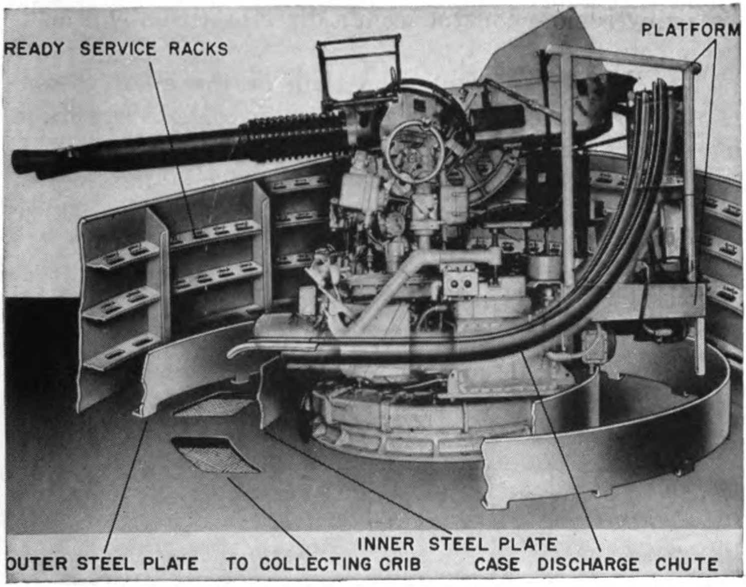


Figure 8–5.—Ammunition disposal facilities for a 40-mm twin mount.

stored in sealed metal boxes containing 16 cartridges each. The ammunition is assembled into clips of four cartridges. The boxes go up by hoist to the CLIPPING ROOM, where they are opened, and clips of fresh ammunition are handed up to the mount crew through a hatch in the deck. Figure 8–4 illustrates an installation that works this way. Many 40-mm mounts, however, have less elaborate ammunition supply facilities.

To dispose of expended cartridge cases, 40-mm mounts have CASE DISCHARGE CHUTES (fig. 8–5). As used cases are ejected from the gun, they are guided by a curved cartridge case deflector into the CASE DISCHARGE CHUTE just behind the slide, which drops them through openings in the mount deck to wire COLLECTING CRIBS below.

40-mm Controls and Drives

The 40-mm mount is at present the smallest U. S. naval mount fitted for power elevation and train by local control or by remote control from a director (usually a lead-computing type).

Power drives in either the twin or the quad 40-mm mount may be either electrohydraulic (Mk 5 or Mk 6 drive) or all-electric Amplidyne (Mk 4 or Mk 9 drive). To make it easier for you to associate each 40-mm mount now in use with its own power drive, they are listed here in tabular form.

40-mm Mount and Drive Assemblies

Mount	*Number of guns*	*Drive (elevation and train) and Manufacturer*
Mk 1 Mods 6, 10, 12, 14	Twin	Mk 5 and Mods (electrohydraulic) by York Safe & Lock Mfg. Co.
Mk 2 and Mods	Quad	Mk 5 and Mods and Mk 6 and Mods (electrohydraulic) by York Safe & Lock Mfg. Co. *Note:* Mk 6 and Mods are for training gear only; Mk 5 and Mods are used for elevating gear.
Mk 3 Mod 4 (Army type, but with power drive)	Single	Mk 10 and Mods (electrohydraulic) by Westinghouse Mfg. Co.
Mk 4 and Mods	Quad	Mk 9 and Mods (Amplidyne all-electric) by General Electric Co.
Army type M3	Single	Manual drive only.

All 40-mm mounts can be mechanically positioned in train and elevation by turning the handwheels at the pointer's and trainer's stations (MANUAL CONTROL). In LOCAL POWER CONTROL the pointer controls the train and elevation power drives to position the gun.

Now let's look in further detail at the mounts powered by the York Safe & Lock electrohydraulic drive and by the GE Amplidyne drive. These include the mounts Mk

1 Mods 6 and up, the Mk 2 and mods, and the Mk 4 and mods.

The earlier Amplidyne-driven mods of Mk 1 (not listed above) are practically obsolete and rarely found in the Fleet. The Mk 3 Mod 4 single mount, an Army type which uses a different electrohydraulic power drive from the York Safe & Lock, is now a rarity too. The M3 single is the Army hand-operated air-cooled mount with the lower carriage removed, and is found only on a few small naval craft. These types are all now so infrequent that they won't be taken up in this course.

40-mm Twin Mount—York Safe and Lock Drive

Let's look first at the Mk 1 Mod 6 (and up) twin mounts fitted with Mk 5 (YS&L) electrohydraulic power drives. The hydraulic A-end and B-end of this drive are Vickers axial-piston units. (Look them up in chapter 4 to refresh your memory.) B-end functioning is regulated by A-end yoke position, and the yoke is positioned by a booster piston. Chapter 7 outlined how the synchro unit, through an amplifier, stroke motor, and control valve, controls the booster piston. Here we'll concentrate on the details of the controls.

At the pointer's station (fig. 8–6) you can see the elevation handwheel, LAG METER, and power selector lever. The lag meter's scale has its zero at the center of its scale. The meter hand's deflection from zero shows how the mount is responding to gun order. The greater the deflection, the larger the difference or ERROR between gun order and gun position. The meter can be used for getting the mount into approximate synchronism with gun order when switching from local to automatic. In theory, the indicators can also be used for indicating control (equivalent to matching pointers), but it's rarely done in practice. Air targets at short ranges move too fast to be tracked properly this way.

The pointer has the firing pedal and firing switch—and something else—the CONTROL HANDLE UNIT, or JOYSTICK.

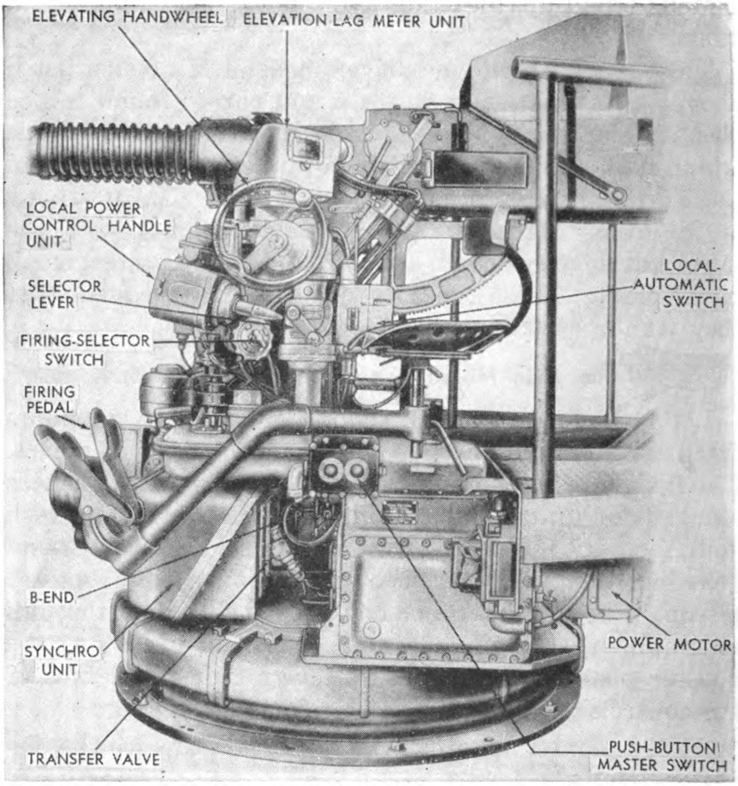


Figure 8—6.—40-mm twin mount Mk 1 with YS&L drive. Pointer's station.

In MANUAL control, here as in other mounts, the pointer and trainer work the handwheels to position the mount mechanically. But in LOCAL and AUTOMATIC control the handwheels are disconnected and play no part in controlling the power drives. In local the pointer alone positions the mount with the joystick. Pushing the joystick down is like pushing the breech end of the guns down—the guns elevate. Tilting it upward makes them depress. Pushing it to the right causes train to the left, and pushing it leftward, causes train to the right. The more the joystick is moved, the more rapid the mount's motion.

The selector lever permits the pointer to select the type of control required. In MANUAL, it connects the handwheels to the elevating gear, and opens the transfer valve to bypass the elevation B-end, so that the elevating gear will not be hydraulically locked when the pointer works his handwheels. The selector lever, when set to LOCAL, positions the local-automatic switch to permit control by the joystick or, in AUTOMATIC, by gun order from the director. A power interlock switch connected with the selector is closed to permit starting the power motor only when the selector lever is set at MANUAL.

At the trainer's station most of these control arrangements are similar, except for the joystick. The trainer cannot position the mount in local; the pointer has full control.

40-mm Quad Controls and Drives

Now let's move on to the quad mounts.

The Mk 2 quads (fig. 8–7) are driven in elevation by Mk 5 YS&L power drives (like those used in the twin mount) and in train by Mk 6's. (The Mk 6 drive is similar to the Mk 5, except that it's modified to handle more efficiently the increased rotating weight of the quad mount.) The Mk 2 quad has no special features that need detain us here; so we can now take up the Mk 4 quad (fig. 8–8), equipped with Mk 9 Amplidyne power drive.

We can't go into detail in this course, but, briefly, all Amplidyne drives for gun mounts in use in the U. S. Navy work on the same basic principle. They all depend on a special AMPLIDYNE GENERATOR. This generator, driven at constant speed by an electric motor, is capable of a large direct-current output that can be instantly controlled as to both amount and direction by a relatively small signal current. In fact, the Amplidyne generator is a sort of electrical A-end with a direct-current motor as its B-end.

The other important units in the Amplidyne drive are a constant-speed power motor to drive the generator, a control amplifier whose output is a signal that regulates gen-

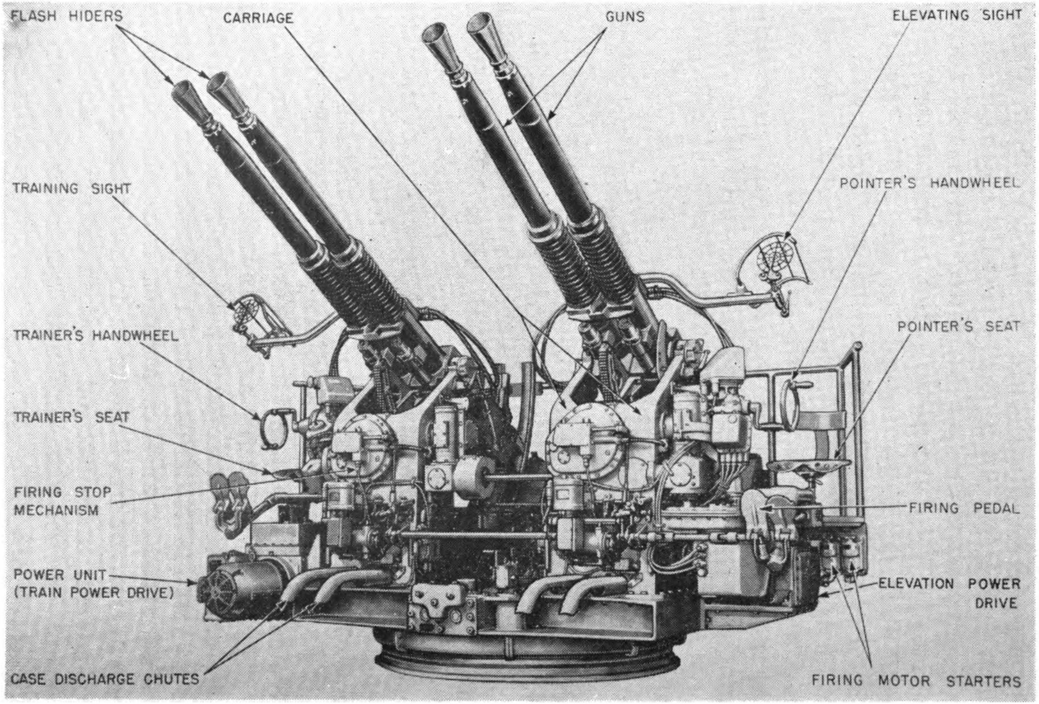


Figure 8–7.—40-mm quad mount Mk 2.

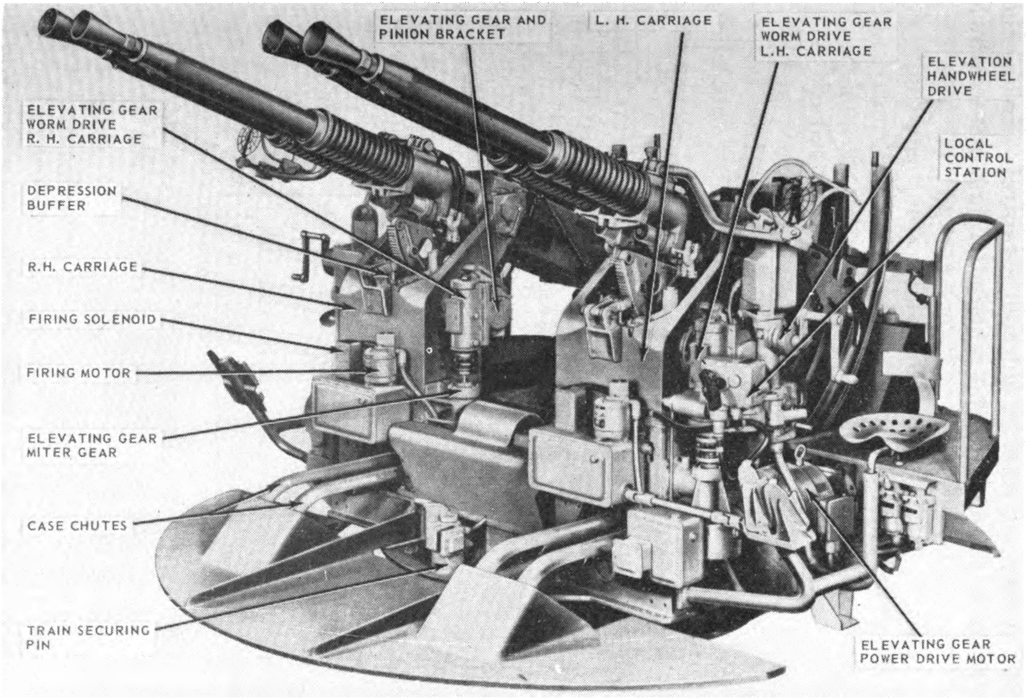

ELEVATING GEAR AND PINION BRACKET
L. H. CARRIAGE
ELEVATING GEAR WORM DRIVE L.H. CARRIAGE
ELEVATION HANDWHEEL DRIVE
ELEVATING GEAR WORM DRIVE R. H. CARRIAGE
LOCAL CONTROL STATION
DEPRESSION BUFFER
R.H. CARRIAGE
FIRING SOLENOID
FIRING MOTOR
ELEVATING GEAR MITER GEAR
CASE CHUTES
TRAIN SECURING PIN
ELEVATING GEAR POWER DRIVE MOTOR

Figure 8–8.—40-mm quad mount Mk 4.

erator output, and a synchro unit connected to the control amplifier input.

The system works very much, in principle, like the YS&L system, at least in automatic control. Follow the explanation through on the schematic, figure 8–9, which

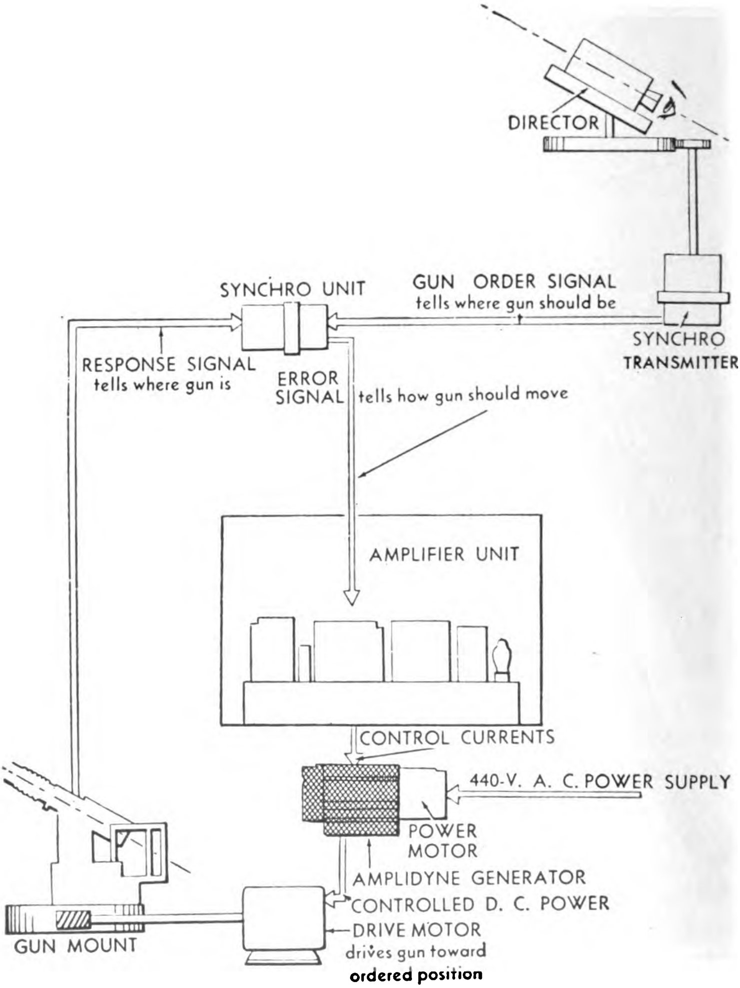


Figure 8–9.—40-mm quad mount Mk 4. Schematic of train Amplidyne power drive in automatic control.

shows an Amplidyne train power drive and control system in automatic.

1. The GUN ORDER SIGNAL from the director goes to the synchro unit (which contains synchro control transformers). This unit also receives mechanically the RESPONSE SIGNAL from the gun, which tells what the gun position actually is.
2. From these two inputs the synchro unit develops an ERROR SIGNAL, representing the difference between gun position and gun order.
3. This signal goes to the amplifier, where it is made powerful enough to control the Amplidyne generator.
4. In the Amplidyne generator the control current from the amplifier regulates direction and amount of direct-current output to the drive motor, which drives the mount to the ordered position.

As in other 40-mm mounts, manual control in the Mk 4 means use of the pointer's and trainer's muscle. However, neither a joystick nor handcranks are used in local. Instead, note in figure 8–10 the following two features:

One is the POINTER'S CONTROL PANEL, located at about eye level. At its top is a FIRING ORDER INDICATOR. When lit up, this tells the pointer to set his firing-selector switch and firing pedal so that the director can control the firing of the mount. Just below this indicator are the train and elevation correspondence indicators, and, below them, START and STOP controls for the elevation and train power motors.

The other feature is the LOCAL CONTROL STATION. This is a metal box mounted on a bracket hinged so that it can be swung out of the way in manual. When the mount is set for local, the handcrank is disconnected by a clutch, and the box is swung out and locked in operating position.

The pointer controls mount movements in elevation and train with the two control handles on either side of the local control station. By grasping the two control handles and turning the control station on its vertical axis,

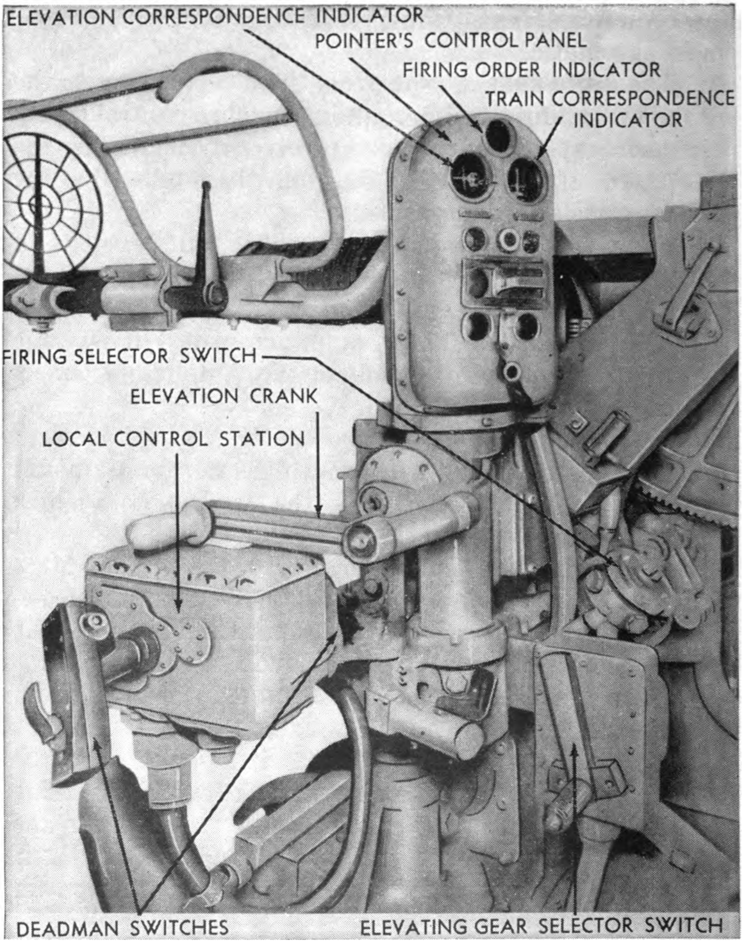


Figure 8–10.—40-mm quad mount Mk 4 with Amplidyne power drive Mk 9. Pointer's station.

he can train the mount in either direction. To elevate or depress the gun, he twists the handles on the box about a horizontal axis. The rate of train or elevation depends on how fast and how far he turns the controls.

Just as the Navy has borrowed the joystick from the airplane for the Mk 5 electrohydraulic drive, it has borrowed the DEAD-MAN SWITCH from the streetcar for the Mk 9 drive. There are two of these switches, one in each handle of the control station. The pointer, by keeping a firm grip on the control handles, keeps these switches closed. If he is put out of action or for some other reason releases the handles, the local power circuits are broken and the brakes automatically go on. Another switch, in the outboard handle, makes it possible for the pointer to continue to operate the mount under power in emergencies even when overload relays have opened the normal power circuits.

The trainer's station in the Mk 4 mount is considerably less complex than the pointer's. There are no firing controls, only one correspondence indicator (for train only), a train handcrank, and a selector lever for the three types of control. In local, the trainer cannot position the mount; the pointer has full control.

40-mm Crew Stations and Duties

The size of the 40-mm gun crew depends upon the size of the mount—whether it is single, twin, or quad.

The crew of a single consists of four men—pointer, trainer, and two loaders.

In the crew of a twin there are seven men—pointer, trainer, gun captain, and four loaders (two for each gun).

The quad crew numbers eleven—pointer, trainer, gun captain, and eight loaders.

Note that the single mount needs no gun captain, and that each individual gun must be serviced by two loaders.

The gun captain is responsible for the functioning of the gun, the smooth teamwork of the crew, and the readying of proper auxiliary equipment. He oversees the firing, reports casualties and directs their correction, and enforces safety precautions. In case of casualty among the crew he steps in as pinch-hitter.

When the mount is under local control the pointer moves the mount in elevation and train and fires the gun by depressing the foot pedal.

In automatic control, the pointer must keep the foot pedal depressed for the gun to be fired from the director. Under director control the trainer stands by.

The first loader stands on the gun platform and places the clips of ammunition in the automatic loader. The second loader stands on deck behind the mount, and, taking the clips from the rack or nearby ready box, passes them up to the first loader. The second loader moves in train with the mount, quickly shifting position as need be. He must also be quick to get his clip of ammunition out of the way during hangfire or similar stoppage.

40-mm Safety Precautions and Casualty Procedures

Let's briefly review safety precautions necessary on 40-mm guns.

1. The No. 1 safety precaution for you to bear in mind with the 40-mm gun is that the firing selector lever (the one on the slide that can be positioned to select AUTO, SINGLE, or STOP FIRE) is NOT A SAFETY. In the event of a stoppage with a live round in the chamber, the gun CAN fire, regardless of the position of this selector. In fact, the gun can fire ANY time the breechblock closes with a live round in the chamber, regardless of the setting of any control. For purposes of safety, you can consider it possible for the gun to fire as long as there is a live round in the chamber, on the tray, or in the loader.
2. Neither the top door nor the side door should be open when it is possible for the gun to fire.
3. Before you attempt to deal with any casualty or stoppage, put the firing selector lever on STOP FIRE. If the breechblock is down and the chamber is empty, release the block to close. But NEVER close the breechblock if there is a live round in the chamber. Lock the block down with the breechblock locking bolt and remove the live round. Remember the precautions concerning misfires and cook-offs.

Now review briefly what to do in case of a casualty.

First determine the point in the operating cycle at which the stoppage occurred. It's especially important (particularly, from the point of view of safety, if the gun is hot) to locate live rounds of ammunition that have gotten past the loader starwheels. And check the positions of all operating controls to catch possible crew errors. Once you've rendered the gun safe and localized the source of trouble, get to work on it. Here are some examples of typical gun casualties, and possible causes:

1. GUN FAILS TO START FIRING. If the gun functioned satisfactorily when last fired that same day, or the day before, the chances are good that it's a crew error. Examples:
    a. Ammunition not properly placed in loader.
    b. Hand-operating lever was not moved far enough to rear.
    c. Hand-operating lever not in forward catch bracket.
    d. Firing-selector lever not properly positioned.
    e. Firing pedal not fully depressed.
2. GUN FUNCTIONS NORMALLY BUT LOADER FAILS TO FEED. Most often this is caused by improper loading of the clip, causing the rounds to jam, and the starwheels to fail to feed. To free them, insert the pawl depressor tool to hold back the feed and stop pawls. The free rounds can then be cleared by hand. Use either end of the pusher tool to pry the jammed rounds loose. Failure to feed may also result from short recoil or a twisted crankshaft.
3. GUN STOPS FIRING WITH BREECHBLOCK DOWN AND CHAMBER EMPTY. Lock the block with the locking bolt. If there is a live round on the tray, remove it through the back door. Unlock the breechblock. Trip the extractor release lever; if the breechblock rises, the breech closing spring is OK. Recock the gun, and attempt to resume fire. If this doesn't work, look for a twisted crankshaft, broken extractors, or worn tray catch lever.

4. MISFIRE (gun stops with breech closed and round in chamber). Follow the usual misfire/cook-off procedure. When danger is past, open the breech and look for a defective firing pin or twisted crankshaft.
5. GUN FIRES BUT EXTRACTION IS SLUGGISH, OR EXTRACTORS FAIL TO FUNCTION, OR BREECH FAILS TO OPEN. Look first for a twisted crankshaft or broken extractor. (Note: Replace both extractors if one breaks.)
6. BREECH FAILS TO CLOSE. Broken breech closing spring, breechblock jammed, or obstruction (example—fragment of damaged case) in breechway.

References on 40-mm Mounts

For further details on 40-mm guns and mounts, see the following references:

Reference publication No.	*Reference publication title*	*Coverage*
OP 820	40-mm AA gun; 40-mm Machine Gun Mechanism Mk 1, Mk 2	Gun mechanism, barrel, etc.
OP 821 and 821A	40-mm Mount Mk 1 and Mods	Twin mount (YS&L power drives)
OP 822	40-mm Mount Mk 2 and Mods	Quad mount (YS&L power drives)
OP 1329	40-mm Mount Mk 4 All Mods	Quad mount (GE Amplidyne power drives)
OP 1289	40-mm Mount Mk 3 Mod 4	Single mount (Westinghouse power drives)
TM 9–252	40-mm Automatic Gun M1	Army gun mechanism & mount
TM9–1252	40-mm Gun Mount M3	

3"/50 RAPID-FIRE GUNS AND MOUNTS

Since the end of World War II, the 3-inch gun has been displacing the 40-mm as the medium-weight antiaircraft armament on modern combat ships. But the 3-inch mounts that have been pushing the 40-mm out are not the manually driven pedestal-type single mounts so widely used in World War II. They are new semiautomatic guns with automatic power-driven loaders, installed in dual-purpose power-driven open twin or single mounts. Primarily intended for defense against aircraft, they are equipped also for use against surface targets. They were planned during World War II when a need developed for a rapid-fire gun with a larger explosive projectile that could stop a suicide plane. The 3"/50 mount was not completed in time to be used in combat in World War II, but it has proved its effectiveness since.

These 3-inch RF mounts use fixed ammunition with electric-primed propelling charges. (Old-style 3-inch guns fire by percussion only; the ammunition is therefore NOT interchangeable.)

3"/50 RF Mounts—General Description

The 3"/50 mounts are more than tactical substitutes for the 40-mm. They are replacements. The twin 3"/50 will actually fit on the quad 40-mm base ring, and the single 3"/50 similarly can be substituted for the twin 40.

The 3"/50 rapid-fire mounts now operational in the Fleet are the outwardly identical twins Mk 27 mod 3 (fig. 8–11) and Mk 33 mods 0, 2, 4, 6, 7, and 8; and the single Mk 34, mods 0 and 1 (fig. 8–12). All use the same gun and similar loading mechanisms (except that in the twin mount the assemblies are of opposite hand). The two marks of twins are similar in nearly all details except the slide. The Mk 27 was originally designed for percussion fire, but has now been converted to electrical fire; the Mk 33 was already set up for electrical fire when issued to the Fleet. The Mk 33 slide design also makes regunning a simpler operation than it is on the Mk 27.

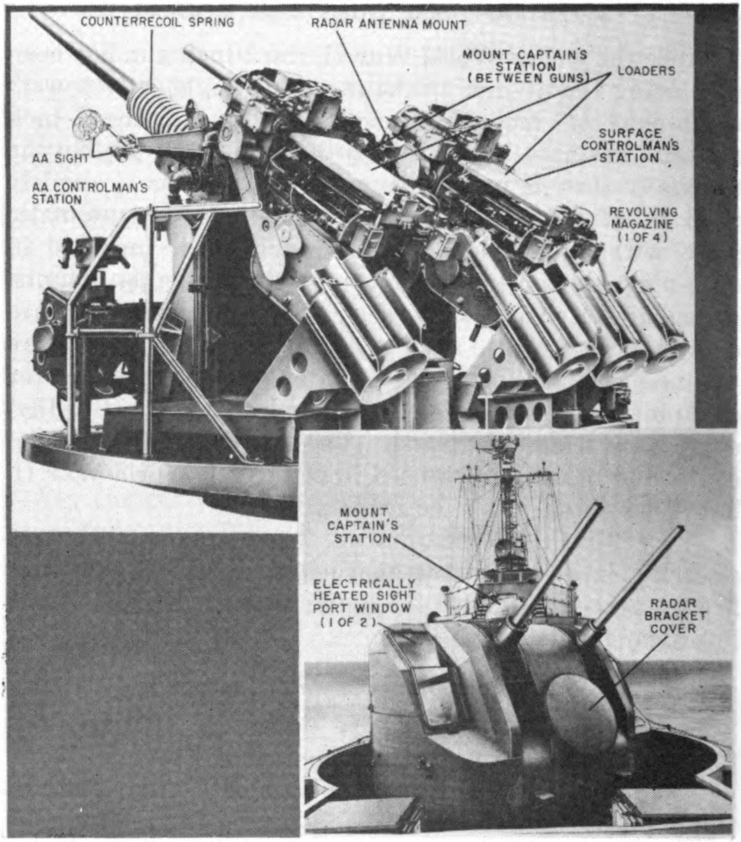

COUNTERRECOIL SPRING
RADAR ANTENNA MOUNT
MOUNT CAPTAIN'S STATION (BETWEEN GUNS)
LOADERS
SURFACE CONTROLMAN'S STATION
AA SIGHT
AA CONTROLMAN'S STATION
REVOLVING MAGAZINE (1 OF 4)
MOUNT CAPTAIN'S STATION
ELECTRICALLY HEATED SIGHT PORT WINDOW (1 OF 2)
RADAR BRACKET COVER

Figure 8–11.—3"/50 RF twin mount Mk 27 Mod 3. (Mk 33 is externally similar.) Inset: 3"/50 twin enclosed mount Mk 33 Mod 4.

The Mk 33 Mods 4 and 7 are ENCLOSED twin mounts with aluminum shield. Mod 4 is shown in figure 8–11 (inset). The other mods are twins with modifications for installation of Gunar, or for substitution of aluminum platforms instead of steel.

The Mk 34 mount (fig. 8–12) is an open single, similar in controls and equipment to the twin, and with a right-hand slide and loader assembly.

Now let's look at the gun itself. The barrel of the 3"/50

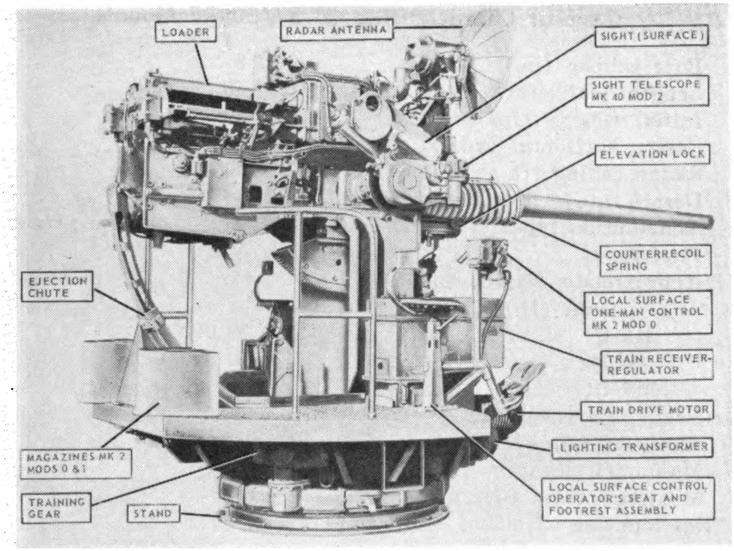


Figure 8–12.—3"/50 RF single mount Mk 34 Mod 1.

is a one-piece, rifled, chambered tube, with its breech end locked to the housing by a bayonet-type joint.

The housing contains the breech mechanism which is a vertical sliding-wedge breechblock type with several additional features. For further details on the breech mechanism, see chapter 9.

The slide supports the recoiling parts (gun barrel and housing) on bearings. Recoil and counterrecoil movement are controlled by a hydraulic recoil cylinder and a large counterrecoil spring surrounding the barrel.

The slide, gun, and housing in turn are supported by the carriage. The slide trunnions rest in roller bearings at the top of the carriage. A large elevating arc secured to the slide meshes with the elevating pinion of the mount elevation power drive system.

The stand is a deck-flange, ring-shaped design which includes the training circle and the stationary roller path. In train, the mount is driven by a power motor which rotates the training pinion.

General Characteristics of 3"/50 RF Mounts

Bore caliber (in.)	3
Length (calibers)	50
Initial velocity (fps)	2,700
Range, horizontal (yd.)	14,200
Range, ceiling (ft. at 85° elev)	30,400
Design rate of fire (rpm)	45
Ammunition type	Fixed, electric primed
Fuze type	VT
*Approximate weight, complete mount (1b)	
Mk 27	31,000
Mk 33	31,000
Mk 34	17,000
Train rate (deg./sec)	30
Elevation rate (deg./sec)	24
Maximum elevation (deg.)	85°
Maximum train (deg.)	720°

*Not counting off-mount equipment

Reference publications on 3"/50 mounts are OP 1753 on the twin mounts, OP 1698 on the single, and OP 1566 on the loader.

So much for the 3"/50 rapid-fire mounts in general. Let's now look more closely at their distinguishing features. We'll begin with the loader.

3"/50 Automatic Loader

The loader (fig. 8–13) is an independent, electric power-driven machine mounted on the after part of the slide. It mechanically loads each gun at the rate of 45 rounds per minute as long as ammunition is served and the firing control is operated.

The major loader components are:

1. Loader drive unit.
2. Hopper.
3. Left-side plate.
4. Right-side plate.
5. Gate operating mechanism.
6. Transfer tray and shell carriage.

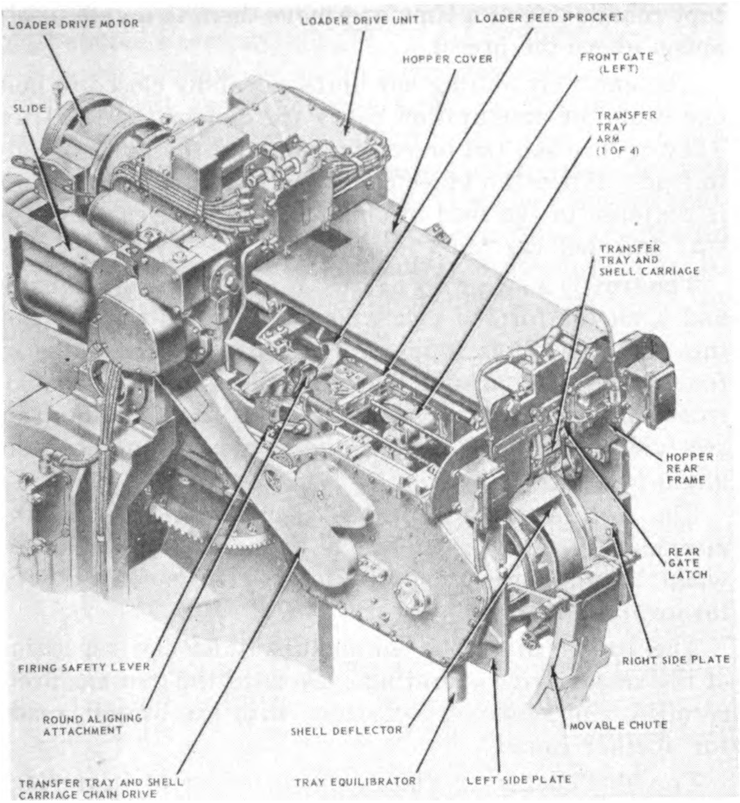


Figure 8–13.—3"/50 rapid-fire gun. Automatic loader Mk 2 Mod 3. (Exterior.)

7. Breech interlock mechanism.
8. Buffer bar and shell deflector.
9. Control system.

The side plates and the drive main housing of the loader are bolted to the gun slide. The loader drive unit consists of a 3-hp motor and various chain and gear drives, through which the loader mechanical components are driven. Two transverse frames across the top of the side plates support the hopper and shell feed mechanism, which are protected by a top cover. Ammunition is fed through the sides into the feed sprockets, which accept rounds one at a time and move them to a gate mechanism above the breech.

The gates are sliding bar units, normally closed to hold one round of ammunition ready for delivery to the tray. They open when the breech is open and the gun is ready to load. When the gates open, the round of ammunition is centered in the feed mechanism and is released to the tray and shell carriage.

The tray is a swinging carrier for ammunition transfer and a mount for the mechanism that rams ammunition into the gun. It is supported beneath the feed gates by four arms, two pivoted in each side plate. The arms rotate automatically to swing the tray from ammunition receiving position, at the feed gates, to ramming position, aligned with the bore.

The ram device is the shell carriage and its driving mechanism. They catapult the round into the chamber when the transfer tray approaches the bottom of its swing toward the breech.

The breech interlock automatically blocks repetition of the loader drive operating cycle until the gun has fired, recoiled, and returned to battery with the breech, ready for another round.

The shell deflector guides extracted empty cartridge cases out of the gun and into a chute to the case ejector of the carriage.

All these functions are mechanically timed by control devices in the loader drive unit. In addition, each is arranged for selective control from different stations, and all are sequentially interlocked.

Certain operations are performed or controlled by an electric control system. The loader control system is an arrangement of control panels, switches, indicators, and loader-operated limit switches and relays. Two solenoids, controlled and operated through this system, alternately block and open the hopper to control manual feed of ammunition; another initiates the loader drive action for each loading cycle. The loader control station is manned by the mount captain.

Now let's follow the loader's working cycle.

First of all, the shell passers pick up the ammunition from a scuttle on deck and place it in a revolving magazine or ammunition rack. The shellmen (two for each gun) pick it up and feed it into both sides of the ammunition hopper (the top part of the loader, which is intended to receive ammunition). This action is shown in figure 8–14. Guide tracks and alignment devices insure that the ammunition is correctly loaded.

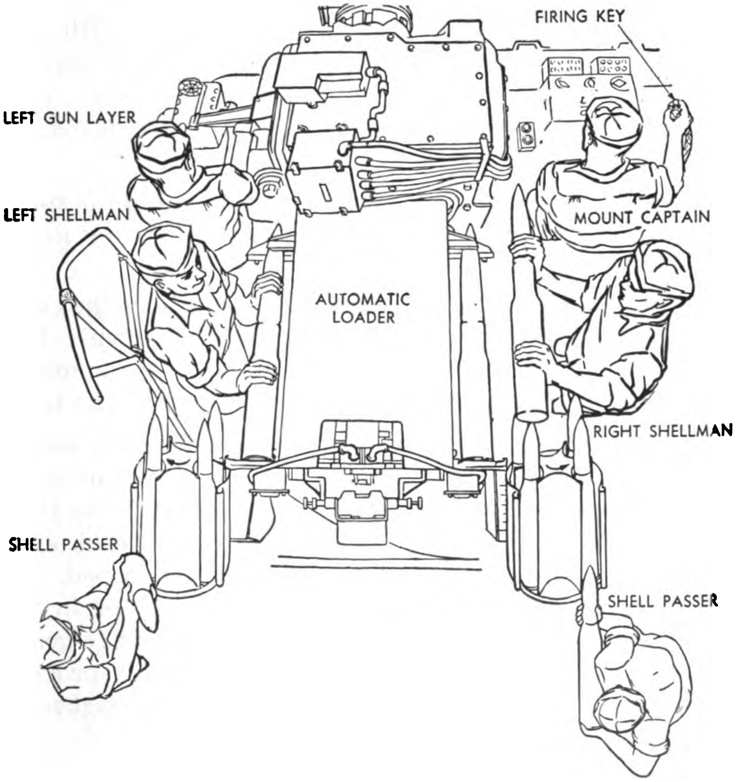


Figure 8–14.—3"/50 rapid-fire gun. Ammunition service to automatic loader.

Inside the hopper (shown with cover removed in fig. 8–15) a system of sprockets draws the ammunition into the feed mechanism. Each of the side sprockets revolves intermittently in one direction, to move ammunition to the center. The center sprocket revolves first in one direction, then in the other, to accept ammunition from the sprockets on either side. The figure shows the sprockets fully loaded with ammunition, and with the cartridges numbered in the order in which they were put into the loader. Sprocket functioning synchronizes with the rest of the loader mechanism to deposit a fresh round in the tray every time it rises to position under the center sprockets. When the loader is first being filled with ammunition, the tray goes through its first three cycles empty. With the fourth cycle, the first round (No. 1 in fig. 8–15B) is on the tray. Let's follow it as it is loaded into the gun breech.

Figure 8–16A shows the ammunition round in the same position as in figure 8–15B, but it also shows the gates (closed) and the transfer tray (up position).

The front gate consists of two I-section bars that can be moved transversely by a control cam (not shown). The rear gate is a spring-loaded latch that keeps the ammunition from drifting aft and helps to position it in the tray.

The transfer tray and shell carriage move each round of ammunition from index position down into line with the gun bore, and catapult it into the breech. The tray is a box structure with two sprockets, one in each end, about which the endless ramming chain is looped. It is supported and positioned by four arms pivoted in the side plates. The two left arms are driven by drive gears mounted in the left side plate. The forward sprocket drives the chain. The shell carriage is an L-shaped casting secured to the chain.

When the loader cycle starts, the front gates move apart, the rear gate releases the cartridge case, and the arms start to swing the tray downward (fig. 8–16B). Two

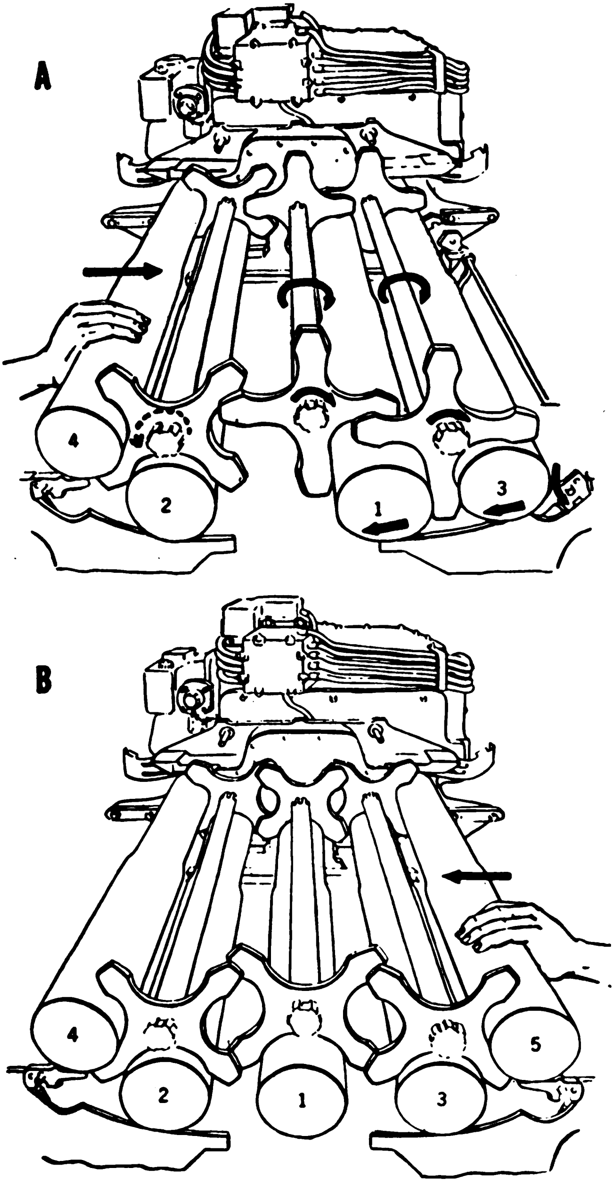


Figure 8–15.—Functioning of 3-inch automatic loader. Sprocket system for drawing ammunition into the feed mechanism.

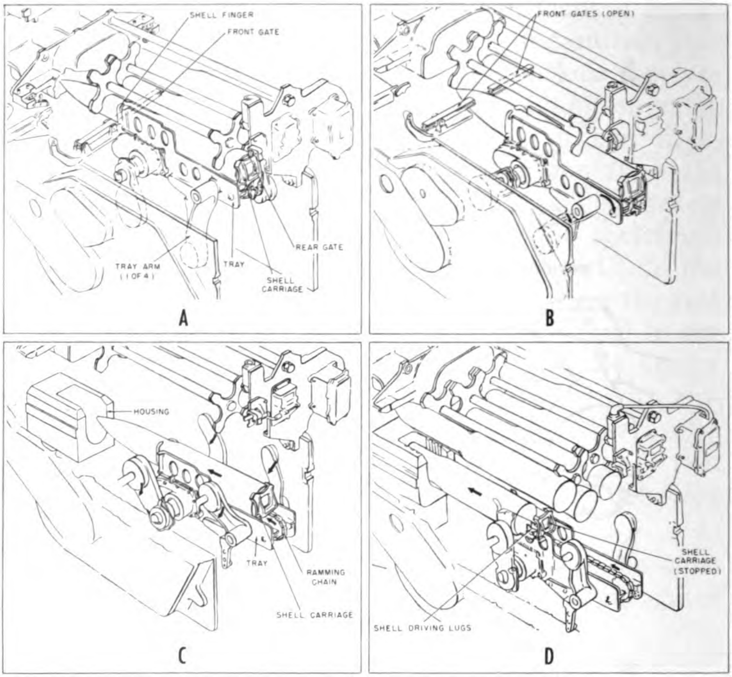


Figure 8–16.—Functioning of 3-inch automatic loader. A. Transfer tray just before gates unlock. (Same stage as fig. 8–15B.) B. Start of tray movement. C. Beginning of shell carriage movement. D. Last stage of chain drive movement.

shell fingers (fig. 8–16B) and shell latches (not visible in the figure)hold the round in the tray. As the ammunition clears the gates, they begin to close again and the feed sprockets begin to index the next round.

When the tray approaches the bottom of its swing (fig. 8–16C), the ramming chain begins to drive the shell carriage forward. A shell driving lug on the chain cams the shell latches and shell fingers to release their grip on the case. At the forward end of its movement, the shell carriage is unlatched from the chain, is buffed to a stop and latched in place, and the chain (through the driving lugs) continues to drive the round, catapulting it into the breech. (See fig. 8–16D.) The velocity of the swinging round is about 9.5 fps as it is released.

At about the same time, a pin on the right front arm of the tray cams the hold-down latch lever of the breech mechanism to unlatch the hold-down device. But the breechblock is not free to rise until the cartridge case rim has tripped the extractors. (See chapter 9 for a discussion of the 3"/50 breech mechanism.)

With the completion of chain forward movement, tray movement is reversed, and so is that of the chain. The tray swings up and the chain moves to the rear, reversing the operations just described. The tray reaches its index position just about the time the breech is closed, and the loader is ready to repeat its cycle after the gun fires.

When the gun fires, the empty cartridge case is ejected from the slide into a chute, through which it goes to an empty-case bin, much as with the 40-mm mount.

All 3"/50 RF Mount Drives, Controls, Sights, and Crew

All 3"/50 rapid-fire mounts have Amplidyne power drives in both train and elevation—Mk 35 power drives on the twins and Mk 36's on the singles. These are roughly similar to the Mk 9's on 40-mm quad mounts Mk 4, and will not be taken up in further detail here.

There are no provisions for manual drive, except handcrank arrangements intended only for stowing and servicing the mount. But there are two types of local control—AA LOCAL and SURFACE LOCAL—plus automatic control from a director. Each side of the mount has a separate control station (similar in appearance and functioning to the one on the 40-mm Mk 4 mount). Local AA is the left gun-laying station (fig. 8–17). Local surface is the right gun-laying station (fig. 8–18).

In AA local, the left gun layer (AA operator) controls the mount in both train and elevation, and fires the gun. The left gun layer's controls consist of a ring sight, a one-man gun-laying control unit with gun firing key in the right-hand grip, a firing cutout indicator, and an emer-

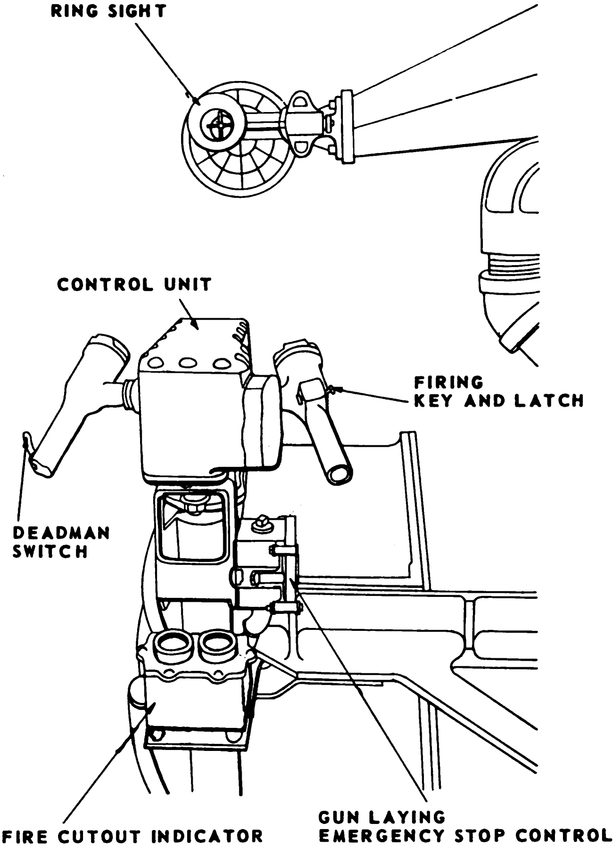


Figure 8–17.—3"/50 rapid-fire twin mount. AA operator's station.

gency stop control. There is no sight-setting provision at this station.

The right gun layer (surface operator) is responsible for starting the elevation and train drive, selecting the control station, laying and firing the guns when the drive selection is local surface, and observing correspondence between gun position and gun order signals. The right gun layer's controls consist of a telescope and open sight, a one-man gun-laying control panel, and a train cable-

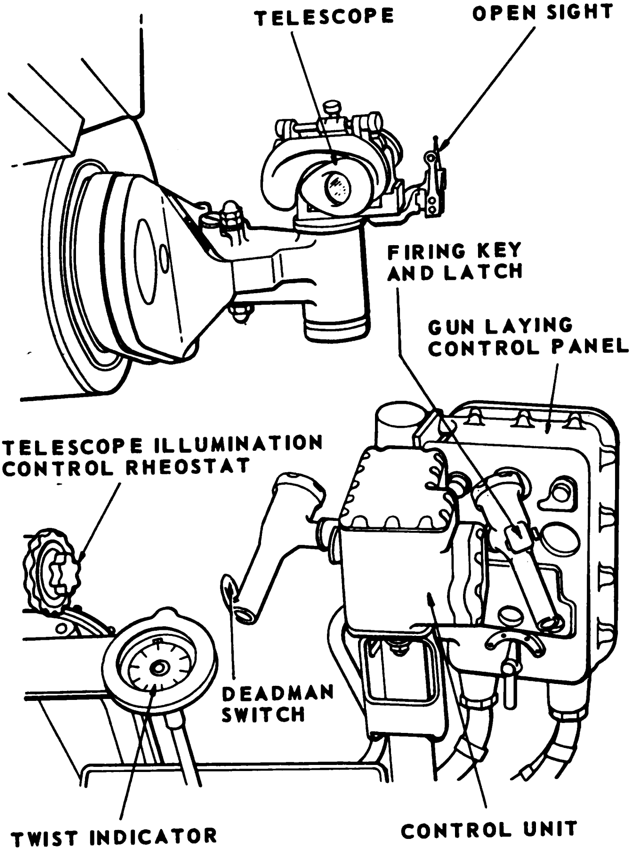


Figure 8–18.—3"/50 rapid-fire twin mount. Surface operator's station.

twist indicator. The gun-laying control panel, on the twin mount, contains a control station selector switch, gun-firing cut-out lights, power-on lights, correspondence-indicator meters to indicate correspondence between gun and mount position and the order signal, and power START and STOP buttons.

The surface sight is a combination open sight and telescopic unit with provision for sight setting. With the AA sight, it is mounted on a yoke astride the slide. The surface controlman, using the open sight, positions the mount to get the target into the comparatively restricted field of view of the telescope. Then he shifts to the scope, adjusting mount position with his controls to keep the crosshairs on the target. Meanwhile the sight setter cranks in deflection and sight angle values in accordance with telephoned orders from the director. There are no synchros transmitting these values.

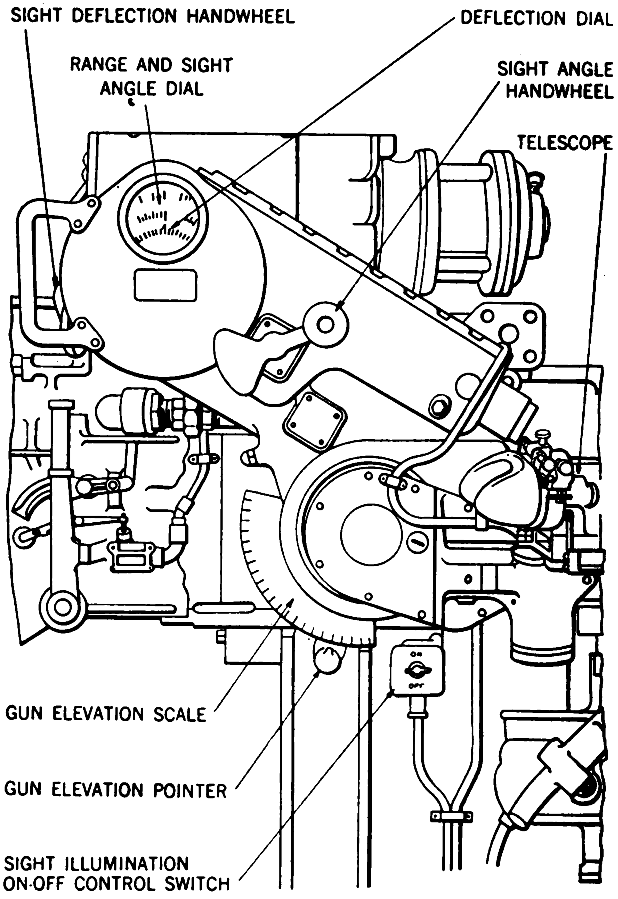

SIGHT DEFLECTION HANDWHEEL
DEFLECTION DIAL
RANGE AND SIGHT ANGLE DIAL
SIGHT ANGLE HANDWHEEL
TELESCOPE
GUN ELEVATION SCALE
GUN ELEVATION POINTER
SIGHT ILLUMINATION ON-OFF CONTROL SWITCH
ON
OFF

Figure 8–19.—3″/50 rapid-fire twin mount. Surface operator's sight.

The sight-angle dial is exceptional in that zero sight angle actually reads on the dial as zero minutes ("0"), not as 2,000 minutes. Zero deflection, however, reads as "500" mils, as in other naval mounts.

The sight setter's station (fig. 8–19) is located directly behind the right gun layer. The sight setter operator receives sight-setting orders by telephone from the director or other fire-control station and sets them into the sight setter's unit. The sight setter is used only with local surface gun laying.

The mount captain's station (fig. 8–20) on a twin mount is between the guns, or to the left of the gun on a

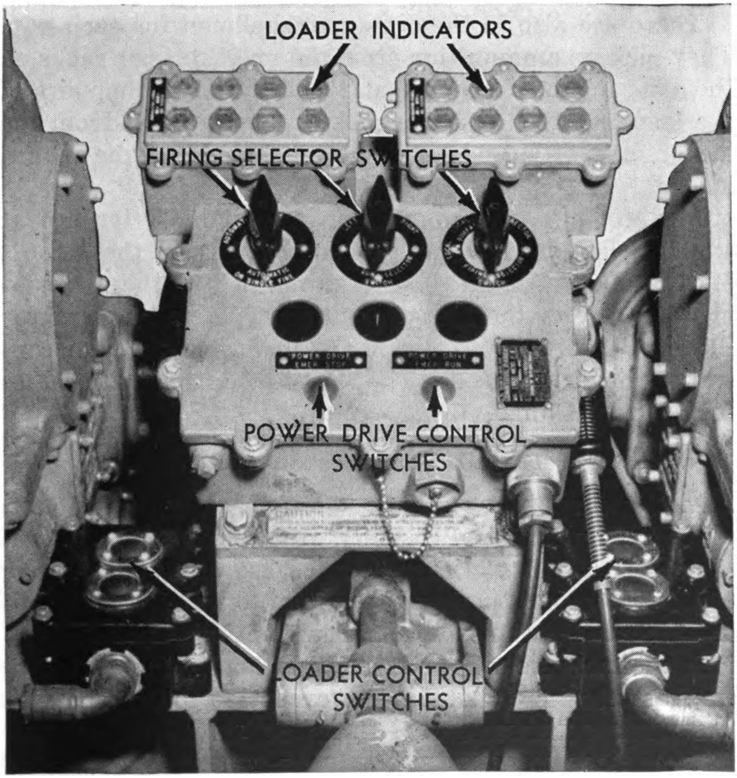


Figure 8–20.—3"/50 rapid-fire twin mount. Mount captain's control station.

single mount. The captain is the supervising gunner and crew captain. His operations are directed by phone by the control officer. He controls both guns with the mount captain's controls. In emergency he stops the firing of either or both guns. His controls allow him to select the control station, switch to single or automatic fire, select the gun or guns to fire, and control the loaders. He also has power-drive emergency stop buttons, and two banks of neon indicators to enable him to check the loader. His firing key must be closed before the loaders will function. It can be latched closed when control of fire is to be at either left or right control station or at the director.

There are also in the crew two shellmen for each gun. They pick up ammunition from the magazines or racks on the after end of the mount and load it into the hoppers of the loaders. Shell passers pick up ammunition from the locker or scuttle and keep the magazines on the mount loaded.

In automatic, the controlmen and sight setter are at standby. The mount may be controlled from the Mk 51, Mk 56, Mk 57, or Mk 63 directors. All of these fundamentally are of the lead-computing type, and, except for the Mk 51, use radar. The Mk 63 incorporates radar control on the mount itself. The Mk 33 mod 2 mount is set up for use with Gunar.

3"/50 RF Mount Casualties

In this chapter, as we've taken up each type of mount, we've briefly reviewed casualty procedures, using several examples of common casualties as "specimens." In the 3"/50 RF mount, the important item to watch is the loader—the most complex mechanical unit ever put on a 3-inch mount. As OP 1566 on this loader is careful to emphasize, "there should be no exception to the rule that CASUALTY CORRECTION IS NEVER TO BE ATTEMPTED BY ANY ONE NOT COMPLETELY FAMILIAR WITH THE WEAPON." This is a good rule in any case, but it is especially applicable in the RF 3"/50 and its loader because of their complexity and novel features. But this book cannot go into the detail that the OP, covers; hence we can do no more here than to set forth the procedure for dealing with casualties in general; for "specimens" and how-to-do-it details, see OP 1566. The section after this will, among others, review safety precautions required when dealing with 3"/50 RF mount casualties.

In general, when there is a loader stoppage or casualty, first locate the affected area as accurately as possible. The mount captain's control panel with its indicators will be of value in this. If the trouble is more serious than a momentary jammed part or minor personnel error, shut off the loader drive. If there is any hazardous element, such as unsafe or misfired ammunition, clear it at once, aim the mount in a safe direction, and evacuate all personnel not immediately concerned. Then go on to perform repairs or readjustments required.

After repair is made, cycle the loader manually with drill ammunition to ensure that it functions properly. With the indicator system energized (but not the power supply contactor) it will be easier to check proper adjustment of parts and synchronization of operations. Lastly, operate the gun and loader a single round at a time, using drill ammunition. Repeat until you are sure the casualty is corrected.

3"/50 RF Mount Safety Precautions

In addition to the usual safety precautions applicable to gun mounts and ammunition generally, note the following special ones that concern 3"/50 RF mounts:

1. OPERATIONAL PRECAUTIONS.
    a. Before firing, always check fluid level in the recoil cylinders and the slide and loader buffers, remove muzzle covers, make sure the case ejector is properly aligned, disengage the slide locking device, and be sure the operating ways of breech, slide, loader, and case ejector are clear.

b. When firing, never force a jammed round of ammunition, or hammer the breechblock home to force a tight case in; unload, and dispose of the round as defective. Never attempt casualty correction with live ammunition in the loader. Instead, unload it. When extracting a live round by hand in case of casualty, open the breech slowly with the hand lever to release the round while another man reaches under the loader to catch it; never let it go into the case chute.

c. After firing, always lock the slide, stow the loader at end-of-cycle position, and stow the breech mechanism with block up and hand-operating lever in its detent.

2. SPECIAL PRECAUTIONS DURING MAINTENANCE OPERATIONS.

   a. Open and tag the 440-v supply switch before working on breech, loader, or power drives.

   b. The gun is breech-heavy, and the elevating gear will overhaul unless braked or locked. Before working on the mount, always set the brake or engage the slide locking device.

OLDER 3-INCH MOUNTS

In spite of their modern features, like automatic ammunition loading and fully director-controlled Amplidyne power drives, the new 3-inch twin and single RF mounts are not completely new. These mounts are, in fact, entirely built around a reliable, combat-tested warrior—the 3"/50 Mk 22 gun which, in World War II, downed many an enemy plane and left its mark on many a blasted enemy vessel.

Although the shiny new rapid-fire mounts make it possible to employ the 3"/50 gun at its full effectiveness, this gun was a powerful weapon even when it was a part of the old manually driven pedestal-type single mount that many Navy veterans of World War II remember so well.

Some of these mounts are still afloat, so let's take them up briefly.

Of these pre-rapid-fire 3-inch mounts, the only ones that you're at all likely to encounter today are the Mk 24 and Mk 26 (fig. 8–21). These mounts are loaded by hand and fired by percussion (using fixed ammunition not interchangeable with that for rapid-fire 3"/50's).

Mk 24 (fig. 8–21A) is driven manually in elevation and train. Although it has no loader mechanism, in many details it resembles rapid-fire 3-inch mounts—particularly in gun and housing design, the sight setter, external counterrecoil spring, and recoil brake. And the breech mechanism (as in all older 3"/50 mounts) is very similar to the rapid-fire type, but minus certain modifications made to accommodate operation with the loader. Mk 24 mounts may be fitted with elevation and train receiver-indicators located at the pointer's and trainer's stations, so that the guns can be controlled by matching pointers. Except for that, Mk 24 is fitted for individual manual control only. The OP on the mount is OP 984.

Mk 26 (fig. 8–21B) is substantially the Mk 22 mount (an earlier design, not illustrated) fitted with Amplidyne drives of Arma manufacture. The counterrecoil spring in the Mk 26 mount is inside the recoil cylinder, but in most other respects (besides the power drive) it closely resembles Mk 24. Fig. 8–21B shows the Mk 26 mount as viewed from the rear. The OP for Mk 26 is OP 2124.

The firing mechanisms for these 3-inch mounts are mechanical linkages operated by depressing a foot pedal at the trainer's station. When the pedal is depressed, the linkage moves a sear in the breechblock, releasing a spring-activated firing pin which sets off the propelling charge by percussion. The set-up is somewhat like the one in the 5-inch gun, except that there is no provision for firing the primer by running an electric current through the firing pin. On mounts fitted for so-called electrical firing, closing the firing key energizes a solenoid which moves the mechanical firing linkage.

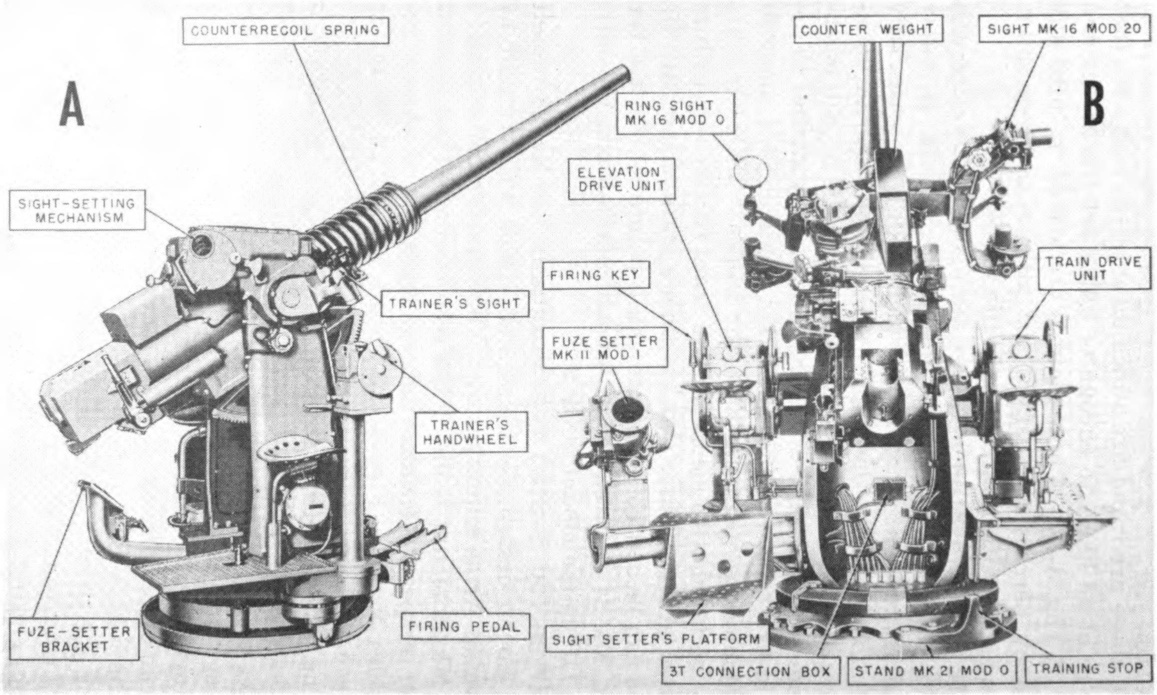


Figure 8–21.—3-inch single mounts (Mk 24 and Mk 26).

For AA work, these 3-inch mounts fire VT-fuzed projectiles, but they are also generally equipped with fuze setters. To set the fuze when time-fuzed ammunition is fired, the projectile's nose is inserted into the fuze setter just before loading and the crank is turned one full revolution. The fuze setter may be regulated by matching pointers on a receiver connected to the director, or regulated in accordance with telephoned data. Where no fuze setter is provided, fuzes may be set by a special FUZE WRENCH.

5"/38 MOUNTS

If you ever get to look at OP 1112, the catalog of gun mounts and turrets in the United States Navy, count the pages devoted to enumeration and description of 5"/38 mounts. You will find that listing and describing them requires over half of that more than 560-page book.

In this chapter it will, of course, be impossible to cover each of these mounts in detail. However, since in other chapters you have already become familiar with many of the important features of 5"/38 armament, we can here survey the outstanding characteristics of the 5"/38 mounts you will be most likely to encounter.

We'll discuss hoists, sights, and power drives, and then briefly describe current marks and mods of 5"/38 mounts. Details of gun mechanisms (breech and firing), and of slide mechanisms such as recoil and counterrecoil gear and elevating gear components, are taken up elsewhere in this course.

5"/38 Mount Features

HOISTS. As you know, ammunition components are passed into an enclosed 5-inch mount's upper handling room through scuttles, or are fed in by the lower ammunition ("dredger") hoists. We won't take up dredger hoists in this course, but let's look a bit more closely at the upper hoists, which haul ammunition from the upper handling room to the gun house. Single 5"/38 mounts have a scuttle in the deck for passing powder, and only one projectile hoist. Twins have both projectile and powder hoists. Let's concentrate for now on the twin mount.

Around the central column of twin mount's upper handling are mounted two sets of projectile hoists and powder hoists, one projectile hoist and one powder hoist for each gun.

The 5-inch projectile hoist not only hauls the projectile to the gun mount, but also sets the projectile fuze. It is more complex than the powder hoist, whose function is only to transport the powder case. Let's consider the powder hoist first.

POWDER HOISTS. The powder hoist in the 5"/38 twin mount (fig. 8–22) is fundamentally an endless roller-type chain, somewhat resembling an ordinary bicycle chain, to which are attached brackets or FLIGHTS at regular intervals. The chain is totally enclosed in a tubular steel HOISTWAY secured to the central column of the mount. It passes, at the top and bottom, over sprockets. The upper or DRIVING SPROCKET is powered by a hydraulic motor (axial-piston type) driven by a balanced-vane pump (in Vickers installations), or a gear pump (in Northern Ordnance installations). The pump is driven by an electric motor. Mechanical linkages, cams, and hydraulic valves control hoist operations.

The hoist may be used either for hoisting powder cases for drill or combat, or for lowering them when taking ammunition aboard. Like an escalator, the chain moves in one direction for hoisting; its movement reverses only when powder cases are to be lowered. Unlike an escalator, it moves intermittently rather than continuously. Every time a case is loaded at the lower end, the hoist moves upward one flight. This is far enough to bring the next empty flight to loading position. Then it stops.

Let's follow through on one operating cycle of the hoist. (One CYCLE is the sequence of operations required to move the hoist through the distance separating one flight from the next.) First, the man at the hoist lower end pushes a

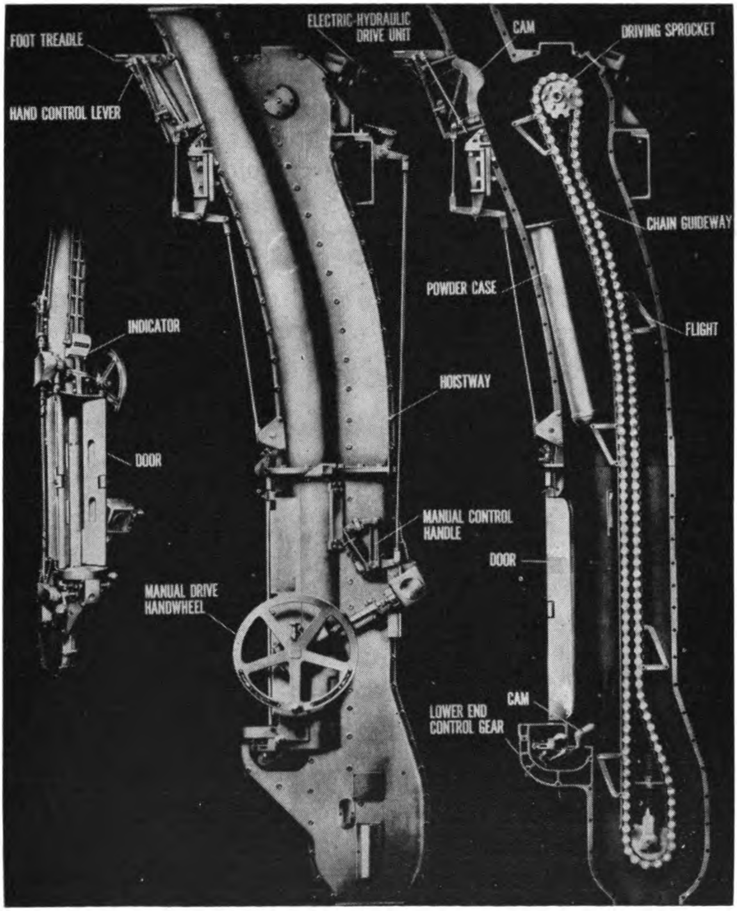


Figure 8–22.—Powder hoist of 5"/38 twin mount.

case in base-up position through the doors, which open inward and are spring-loaded to close. While the doors are open, an interlock positions a control valve to prevent the hoist from moving. When the case has been inserted, it depresses a cam. After the operator has removed his hand and the doors have closed, the cam starts the hoist by actuating the same control valve.

The hoist raises the cartridge case one flight, then stops. The hoist lower end is empty, ready for the next case. When another is loaded, the cycle is repeated.

By the time the third case has been loaded, the first is protruding from the top of the hoist, ready to be picked up. (Longer hoists, of course, can hold more than three cases at one time.) The case also depresses a cam linked to the control valve, so that the hoist cannot start again while the upper end is loaded. The same cam also causes an indicator at the lower end to read FULL when the upper end is occupied, and EMPTY when empty. When the case at the top is removed, the hoist automatically starts to bring up the next case.

A three-position control lever at the upper end can be positioned at HOIST, STOP, or LOWER. The STOP position can be used for stopping the hoist in an emergency when operating under power. The normal position in drill and combat is, of course, HOIST.

When the operator is lowering ammunition, he uses a foot treadle to depress the control cam at the hoist upper end, so that he can insert the case into the hoist. The operator at the lower end uses a hand lever to open the doors for removing the case.

A control lever at the lower end of the hoist provides for POWER or MANUAL operation. In manual, a handwheel is connected to the hydraulic motor output shaft through a clutch in the hydraulic brake assembly. When you turn the handwheel, you move the hoist's endless chain. The handwheel is usually removed and stowed when the hoist is operating in power. The hydraulic brake assembly of which the clutch is a part has two functions. We won't go into its workings here, but this is what it does:

1. The brake stops the hoist automatically if, while operating in power, hydraulic pressure is lost.
2. The clutch permits the handwheel to move the hoist, but does not let movement of the hoist turn the handwheel.

Now let us take up the 5-inch fuze-setting projectile hoist, which is used in both twin and single mounts.

PROJECTILE HOISTS. The part of the hoist that actually does the hoisting consists of an endless roller-type HOIST CHAIN (center chain in fig. 8–23) to which are secured two PROJECTILE FLIGHTS, spaced equally one from the other. The chain is driven by a hydraulic motor through

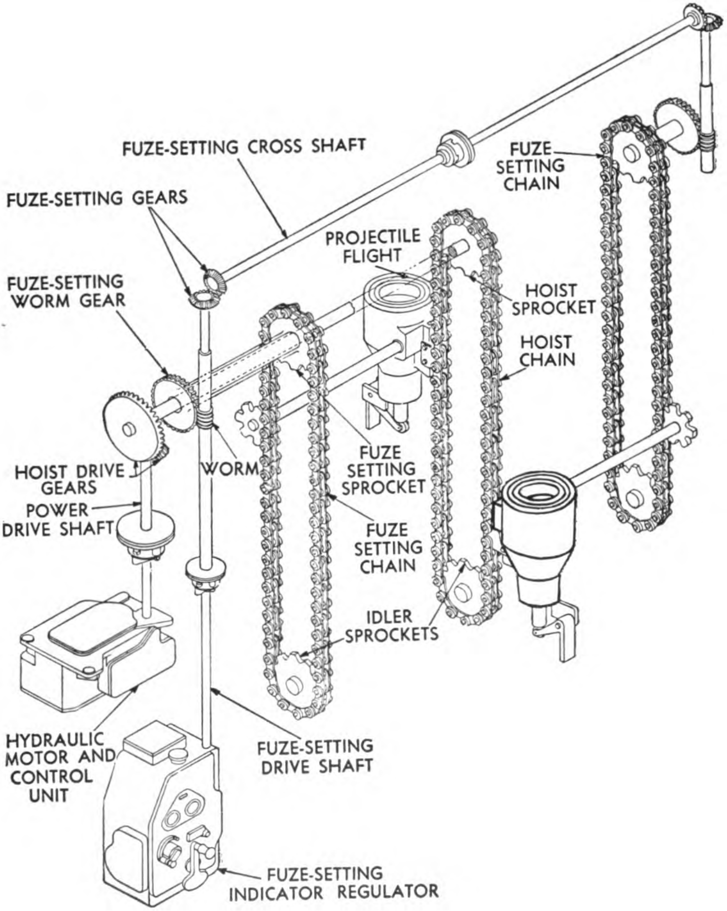


Figure 8–23.—5-inch projectile hoist. (Schematic.)

the top hoist sprocket. Its lower end is engaged by an idler sprocket. However, the hoist chain, instead of moving intermittently in the same direction each cycle, REVERSES its direction each cycle. Like the old oaken buckets in the well back home on the farm, when one flight is at the top of the hoist, the other is at the bottom. When the one on top goes down the other comes up. The one going up contains a projectile; the one going down is always empty. (This hoist is NEVER used for lowering projectiles.)

That takes care of getting the projectile from the handling room at the bottom to the mount at the top. But how does the hoist set the fuze?

The answer involves the two FUZE-SETTING CHAINS, on either side of the hoist chain, which are driven by the FUZE-SETTING INDICATOR-REGULATOR. (In the actual hoist, the three chains are very close together; the wide spacing in the schematic is used to clarify hoist operation.) The left fuze-setting chain is driven through a worm gear and hollow shaft which surround the hoist drive but move independently of it. The right chain is driven at the same time by a worm geared to a cross shaft. The fuze-setting indicator-regulator can be actuated either (in AUTOMATIC) by transmitted data from the fire-control system or (in LOCAL) by a handcrank.

Now let's examine the flight and the fuze it is designed to set.

The fuze has two LUGS: a FIXED LUG is part of the fuze body, and a TIME-RING LUG is part of the fuze's movable TIME RING. (Right, fig. 8–24.) Turning the time ring sets the fuze to explode the projectile at the desired time after firing. The fuze setter's function is to turn the time ring the proper amount, as determined by the fire-control computer or by the fuze-setter operator.

The fuze-setting projectile flight (left, fig. 8–24), is a conical pot secured to the hoist chain. A SPROCKET with a WORM on its shaft engages the fuze-setting chain; the

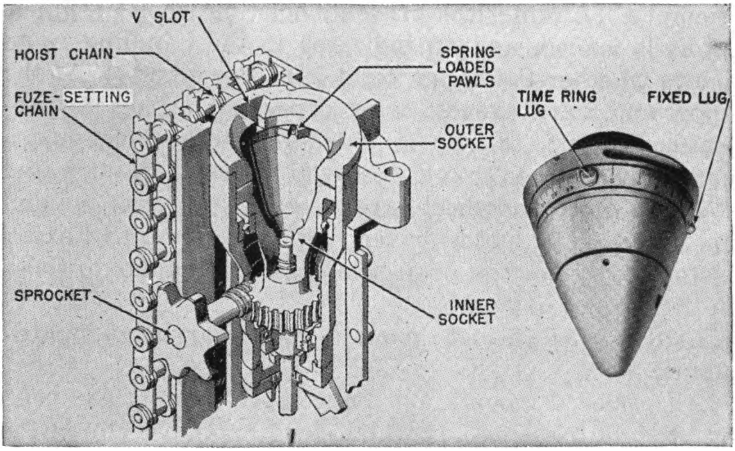


Figure 8–24.—5"/38 fuze and fuze-setting projectile hoist flight.

worm engages a gear secured to the INNER SOCKET of the flight. At the top of the inner socket, which can rotate with respect to the body and OUTER SOCKET of the flight, are two spring-loaded pawls. In the top of the outer socket is a V-shaped slot.

The projectile is put into flight at the bottom of the hoist with the fixed lug in the V-shaped slot. When the flight begins to go up with the hoist chain, the sprocket engaging the chain rotates as it walks up the fuze-setter chain, turning the inner socket. At some point in the flight's upward travel, the spring-loaded pawls on the inner socket engage the lug on the fuze time ring, and continue to turn it as the flight moves to the top. Upon arrival at the top, the fuze is set in accordance with the indicator-regulator's position, and the projectile is ready to be loaded into the gun.

All this happens, of course, in much less time than it takes to tell it. And, you can see, as long as the projectile remains seated in the flight at the top of the hoist, the fuze setting will constantly be transmitted to it.

The hoist automatically goes into operation when a projectile is loaded on the lower flight and the upper one is empty. (An interlock prevents hoisting when the upper flight is loaded, and an indicator in the handling room shows whether the upper flight is full or empty.) At the upper end, a foot treadle, when depressed, pushes the projectile upward, to help in unloading. The hoist has a hydraulic brake to stop it in case of hydraulic failure, and a clutch and handwheel arrangement to permit manual operation. The motor-driven hydraulic pump and axial-piston motor for the projectile hoist are similar to those in the powder hoist.

SIGHTS. All 5-inch mounts have carriage-mounted sights.

All enclosed mounts and many open mounts use prismatic sight telescopes, in which elevating movement of the gun and changes in sight setting shift prisms in the sight optical system, while the sight housings remain stationary.

Some open mounts have combination peep-and-ring and telescopic sights. In these, the sight-seeing mechanism and sight-elevating linkage from the mount's elevating gear move the entire optical system (of the telescopes) and the peep-and-ring assemblies, as sight setting changes and as the gun is elevated and depressed.

In this chapter we will not go into sight optics; instead, we'll concentrate on the mechanics of the gun sights.

As you remember from a previous chapter, carriage-mounted sights move in train with the gun, but unlike slide-mounted sights they can't automatically shift with the gun in elevation unless there is a mechanical linkage in the mount for this purpose. There is such a linkage in all 5"/38 mounts, but one general design is used in single mounts, whether open or enclosed, and quite a different one is used in twin mounts. Much of our discussion here will concentrate on these linkages and their differences. Let's begin with the single mount.

Single 5"/38 mounts use Mk 31 sights. In enclosed mounts and most open mounts the sight mechanical system drives movable prisms; in other open mounts the mechanical system drives the telescope and ring sights. But the mechanical system itself is similar in both—and different from the twin-mount sight arrangement.

You should already be familiar with what you see in fig. 8–25. In local control, the sight setter cranks his handwheels so that the sight dials will match the synchro receiver indications for sight angle and deflection. Or he

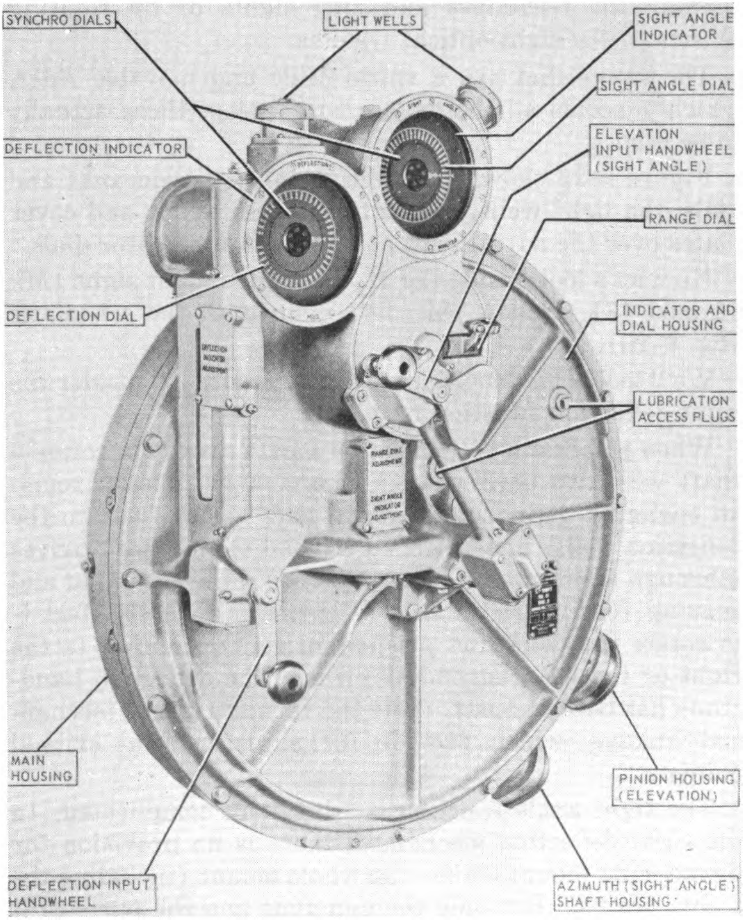

SYNCHRO DIALS
LIGHT WELLS
SIGHT ANGLE INDICATOR
SIGHT ANGLE DIAL
DEFLECTION INDICATOR
ELEVATION INPUT HANDWHEEL (SIGHT ANGLE)
RANGE DIAL
DEFLECTION DIAL
INDICATOR AND DIAL HOUSING
LUBRICATION ACCESS PLUGS
MAIN HOUSING
PINION HOUSING (ELEVATION)
DEFLECTION INPUT HANDWHEEL
AZIMUTH (SIGHT ANGLE) SHAFT HOUSING

Figure 8/25.—5"/38 single mount Mk 37 (open). Sight-setting mechanism.

either uses the fixed index to set the sight dials at settings ordered by phone, or he uses the range dial to set sight angle in terms of range as estimated by the mount captain. The range dial is calibrated in yards, the sight angle dial in minutes (with the indication "2,000" corresponding to zero sight angle), and the deflection dial in mils (with "500" corresponding to zero deflection). His cranking moves the line of sight in elevation or train by turning the telescopes and ring sights or by rotating prisms in the sight optical systems.

The range dial has a spiral scale and movable rider, which conceals all the graduations except those actually to be read.

Figure 8–25 shows, in addition to the handcranks and dials, the light wells, lubrication access plugs, and cover plates over the adjustment points for the indicator dials.

Now let's look inside the 5"/38 single mount sight (Mk 31 mod 18). Follow this discussion with the schematic (fig. 8–26).

We'll look at the mechanism functionally. Consider the sight deflection function first.

When you crank the deflection hand crank, you rotate a shaft with two bevel gears. One gear is linked through an engaging gear, shaft, worm, and worm wheel to the deflection dial. The other, on the end of the shaft, drives (through a worm on its forward end), other shafting and gearing (easily traced on the schematic) whose effect is to rotate the deflection prisms horizontally either to the right or the left (depending on how the deflection handcrank has been turned). Note the verniers in this mechanical linkage, which provide for adjustment at critical points.

The sight angle function is a bit more complicated. In the sight deflection mechanism there is no provision for introducing mount train—the whole mount (including the sight) trains. But only the gun slide and the parts in it move in elevation. The sight angle function must provide

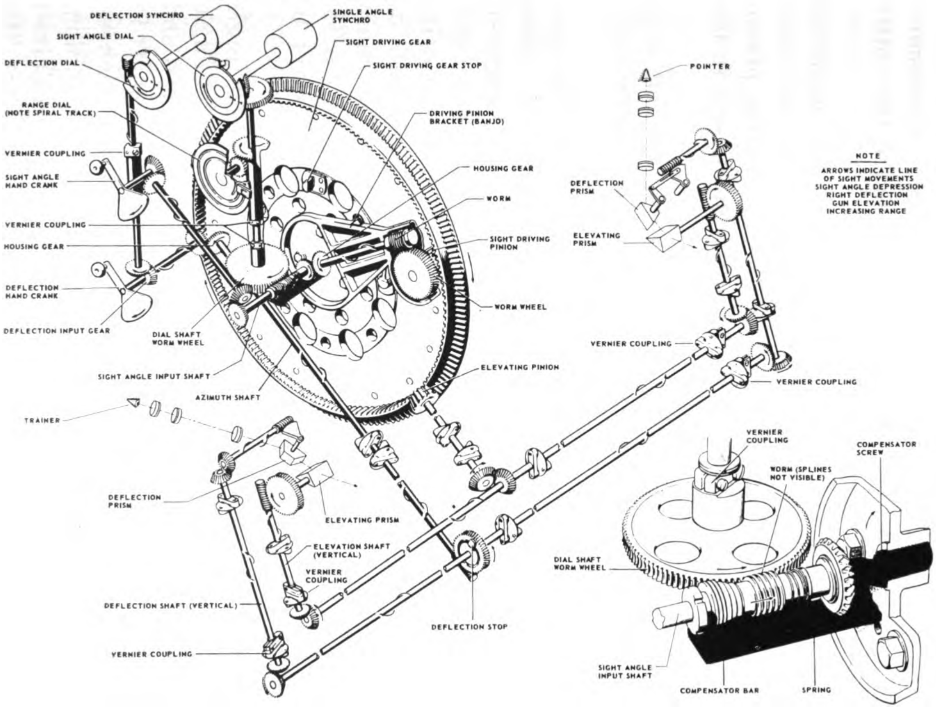


Figure 8—26.—5"/38 single open mount Mk 37. 5-inch sight Mk 31 Mod 9. (Schematic).

for introduction of both gun elevation and sight angle. Let's look at this part of the mechanism.

The DRIVING PINION BRACKET, or "banjo," is a steel casting that houses and mounts the sight elevating worm and worm wheel. It is bolted to the right trunnion, moves with the gun in elevation and depression, and so transmits gun movement to the sight assembly through the SIGHT DRIVING PINION.

The SIGHT DRIVING GEAR is a large bevel gear about 32 inches in diameter, roller-bearing mounted on the right trunnion. Its bevel teeth mesh with the elevating pinion which, through gearing, tilts the elevating prisms in the telescope.

Gear teeth cut in the inside rim of the driving gear mesh with the sight driving pinion mounted in the driving pinion bracket.

Now you can see how elevation movement of the gun moves the line of sight. As the gun elevates, the sight driving bracket (banjo) which is secured to the trunnion clip moves with it. This makes the sight driving pinion, which meshes with the internal gearing of the sight driving gear, drag the sight driving gear around with it, causing the elevating pinion to turn. This turns the main driving shaft, vertical shafts, and telescope input shafts, tilting the elevating prism, causing the line of sight to follow the gun in elevation.

Now, to change sight angle, you turn the sight angle handcrank. Through gearing, this rotates the sight angle input shaft (fig. 8–26). A bevel gear on the inboard end of the shaft meshes with another bevel gear on a shaft in the banjo, and so turns a worm that drives a worm wheel. On the worm-wheel shaft is the sight driving pinion, which meshes with the big sight driving gear as explained above. Turning the sight angle handcrank turns the sight driving gear, and thus the elevation prisms. But note that the worm-worm wheel combination prevents movement of the driving gear, in response to gun elevation movement, from turning the sight angle handcrank.

That's why gun movement in elevation tilts the elevation prisms without turning the sight angle handcrank.

Stops on the sight driving gear limit its motion with respect to the driving pinion bracket—and hence the maximum value of sight angle—to 60°.

Look again at the sight angle input shaft. Besides the bevel gear at its inboard end, it also has a worm in the middle. (See the detailed enlargement in the lower right corner of fig. 8–26.) The worm can slide on splines on the shaft, and is under spring thrust to eliminate lost motion. (The splines are not visible in the schematic.) When the sight angle input shaft is turned (by the sight angle crank) it drives the dial shaft worm wheel, which through gearing drives the sight angle dial and range dial, to indicate the changes introduced into these values.

But this isn't all. There is a reason why the worm is on splines. It will become clear if you consider what happens when the gun is elevated but the sight angle handcrank remains stationary. This, as you already know, causes the banjo to drag the sight driving gear around. But look closely (in fig. 8–26) at the housing gear, and the bevel gear on the inboard end of the sight angle input shaft. The gear and shaft are locked in position by the dial shaft worm wheel. Therefore, as the banjo revolves with the gun trunnion, the housing gear must "walk" around the bevel gear. Obviously, this rotates the worm, which drives the sight driving pinion, the driving gear, and the sights themselves. Thus, if the gun is elevating, turning the driving gear (as you see it in fig. 8–26) counterclockwise, this effect turns the gear slightly clockwise, and causes the line of sight movement to lag slightly the axis of bore movement. The error introduced is, in modern fire control, fairly substantial—about 3° for a change in elevation of 45°. And IT DOESN'T REGISTER ON THE SIGHT ANGLE DIAL.

Clearly, if it did register on the dial, the error would automatically be taken care of. And making it register is the function of the compensator mechanism illustrated in the lower right of figure 8–26. This consists of a COMPENSATING SCREW with a left-hand thread—the screw being secured to the banjo so that it is in the center line of the trunnion—and a sliding compensator bar with a lug on one end and a fork on the other. The lug on the bar is secured to the screw. The fork engages a groove in the sight angle driving worm. The sliding bar prevents the screw from turning with the banjo.

Here's how it works. As the banjo turns, the screw moves in and out of its threads, moving the sliding bar. The bar, in turn, makes the sight angle worm slide on the splined shaft. This drags the dial shaft worm wheel around, and causes the dial to show the change in sight angle.

Follow the arrows in the diagram to get an idea of the motions made by the mechanism.

The trainer's and pointer's telescopes each have a sight angle and a sight deflection prism. The sight angle prisms are moved by sight angle linkage, the deflection prisms by the deflection linkage. Movement of these prisms offsets the line of sight.

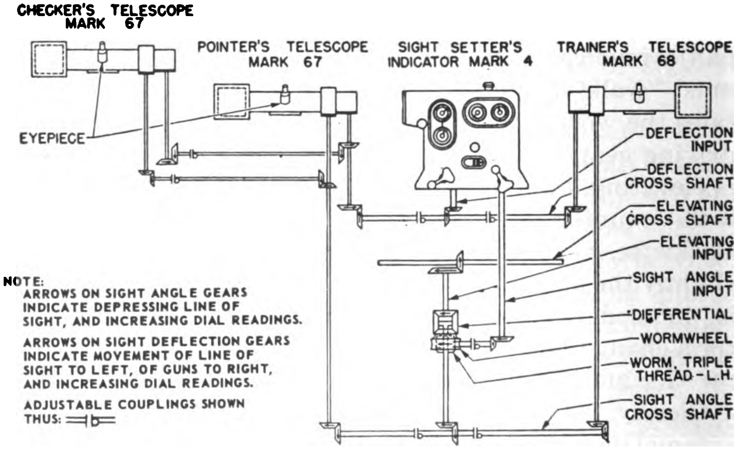

CHECKER'S TELESCOPE MARK 67
POINTER'S TELESCOPE MARK 67
SIGHT SETTER'S INDICATOR MARK 4
TRAINER'S TELESCOPE MARK 68
EYEPIECE
DEFLECTION INPUT
DEFLECTION CROSS SHAFT
ELEVATING CROSS SHAFT
ELEVATING INPUT
SIGHT ANGLE INPUT
DIFFERENTIAL
WORMWHEEL
WORM, TRIPLE THREAD - L.H.
SIGHT ANGLE CROSS SHAFT
NOTE:
ARROWS ON SIGHT ANGLE GEARS INDICATE DEPRESSING LINE OF SIGHT, AND INCREASING DIAL READINGS.
ARROWS ON SIGHT DEFLECTION GEARS INDICATE MOVEMENT OF LINE OF SIGHT TO LEFT, OF GUNS TO RIGHT, AND INCREASING DIAL READINGS.
ADJUSTABLE COUPLINGS SHOWN THUS: ═╡╞═

Figure 8–27.—5"/38 twin mount. Mk 36 sight. (Schematic.)

In other mods of the Mk 31 sight, the sight mechanism drives telescope adapters through independent gearing from the sight angle and deflection shafting. The adapters mount the telescopes and the open sights.

One difference between the Mk 31 sights on open and enclosed mounts is that in the latter there is a CHECK SIGHT telescope on the pointer's side. This is more or less a duplicate of the pointer's sight and its prisms are driven in exactly the same way.

Now let's look at the sight mechanism in twin mounts. As the schematic (fig. 8–27) shows, this is, unlike some of the other features of twin mounts, relatively simple. As with single mounts, the sights move with the gun in train, so sight deflection is simply cranked in by the sight setter and transmitted through gearing and shafting to the deflection prisms in the sight telescopes. The sight angle prisms move both with the sight angle handcrank on the sight setter's indicator, and with gun elevation movement. This is done by feeding both these inputs into a mechanical differential whose output is proportional to their algebraic sum. And that's all there is to it.

Figure 8–27 also shows the points at which are located the adjustable couplings used in sight alignment.

Figure 8–28 shows the twin mount sight setter's station and particularly the sight setter's indicator. Deflection is indicated (in mils) by two sets of ring dials—the lower one coarse and the upper one fine. Inside each set of dials is a disc dial bearing only an index mark. In the lower dial set the disc is driven by the coarse deflection synchro, in the upper one by the fine deflection synchro. The sight angle dials are set up similarly, with the coarse dial set at the left. The range dial is a spirally graduated dial with a cammed movable index, much like the kind on the single mount sight mechanism. The crew operates the sights much as on the single mount.

On many twin mounts the mount captain's station is a hatch at the top of the gun shield, where he mans a ring

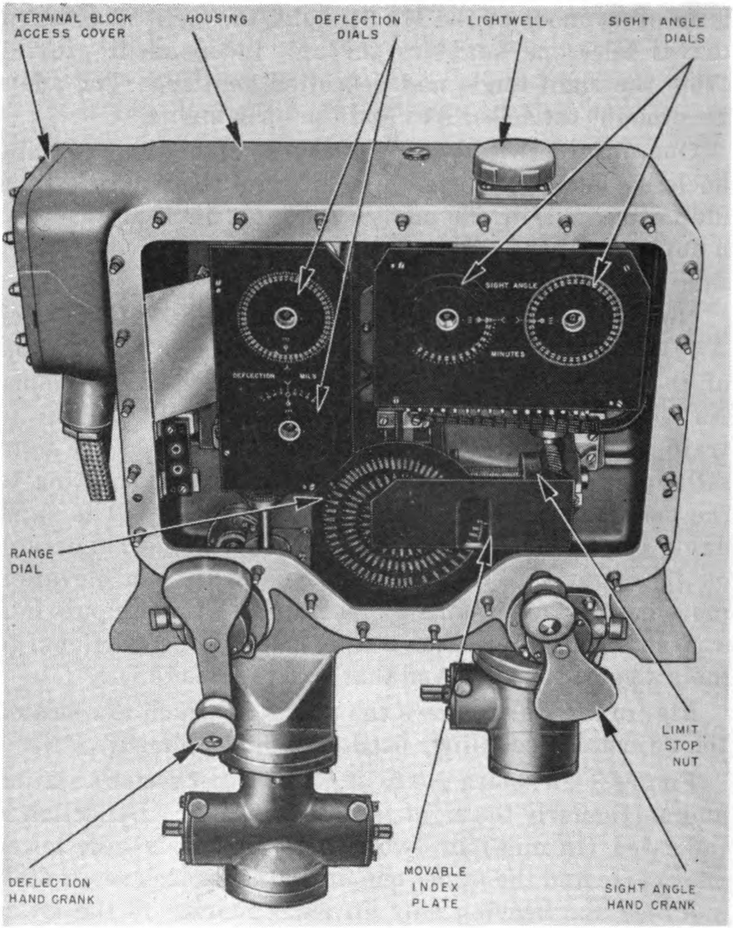


Figure 8–28.—5"/38 twin mount. Sight setter's indicator.

sight whose movements are transmitted by cable to indicators at the trainer's and pointer's stations. The same set-up is used on single 5"/54 mounts Mk 39.

POWER DRIVES. Details on the power drives and control equipment of 5"/38 mounts are beyond the scope of this course, but to round out the picture let's get just a glimpse—a highly simplified prelude to a rather involved subject.

All 5"/38 mounts are driven by electrohydraulic power equipment. As you remember from earlier in this course, an electrohydraulic power drive uses an electric motor to drive a pump whose output can be controlled by changing the angle of its tilt plate without changing speed or direction of rotation. The pump's output drives a hydraulic motor which, through gearing, moves the gun mount in elevation or train.

Twin and single 5"/38 mounts are equipped with this type of drive, using axial-piston pumps and hydraulic motors of either Northern Ordnance or Waterbury design. The main differences between twin and single power drives is in their CONTROL EQUIPMENT. Twin 5"/38 mounts use Ford Instrument Co. control equipment; single mounts generally have control equipment by General Electric. The differences are in the main concerned with the internal design and functioning of the regulating and indicating units, to be taken up in a later course in this series. But we can here discuss the types of control possible with this equipment, without going into the internal details.

There are four general types of control possible with 5"/38 mounts—MANUAL, HAND, LOCAL POWER, and AUTOMATIC. Hand control is possible only on twin mounts (Ford control equipment), which can also be controlled in the other three modes. Single mounts (GE control equipment) can be controlled in manual, local, and automatic, except for those installed on vessels that have no director systems. (Such mounts are capable only of manual or local control.) Throughout this discussion, remember that a mount always has TWO power drives—one for train and one for elevation. We'll take up train; elevation power drives are similar. Although it isn't often done, an individual mount can use one type of control in elevation, and another in train.

In manual, the trainer cranks handwheels which transmit the turning effort by gearing and shafting to the training pinion (fig. 8–29A). The pinion, which is in the base ring, rolls around the training rack in the stand, and the mount rotates in train. In elevation, the pointer cranking the handwheels rotates the elevating pinion, which engages the elevating arc on the slide. This is old stuff to you, of course. The point here is that the trainer (or pointer), operating in manual control, uses his muscle-power through gearing to move the mount.

In hand control (which twin mounts have, but singles don't) the "muscle" is supplied by the electrohydraulic power drive, and the control by the trainer (or pointer). When he cranks the handwheel, the trainer mechanically displaces the A-END CONTROL UNIT'S mechanism, which tilts the A-end tilt plate. This causes the A-end to pump hydraulic fluid into the B-end, driving it so that it trains the mount in the direction required by the turning of the handwheels. As the mount trains, it mechanically drives the A-end control unit's mechanism back toward its "zero" position, so that the mount stops moving when it has trained far enough to correspond with the amount of cranking the trainer has done. Thus the angle of train from the starting position is determined by the cranking by the trainer combined with the "mechanical response" from the mount (fig. 8–29B). You have here a mechanical-hydraulic "feedback loop" on the feedback principle discussed earlier in this course.

In local power control the same principle applies, but the handwheels, instead of working through the mechanical A-end control unit to operate the tilt plate as in hand control, operate a sensitive hydraulic valve system or "hydraulic amplifier" in the mount INDICATOR-REGULATOR. These valves (and their mechanical linkages) regulate the flow of oil into and out of a cylinder whose piston shifts the A-end tilt plate. The mechanical response from the gun mount goes to the valve system to provide feedback (fig. 8–29C).

In automatic control the main difference is that the

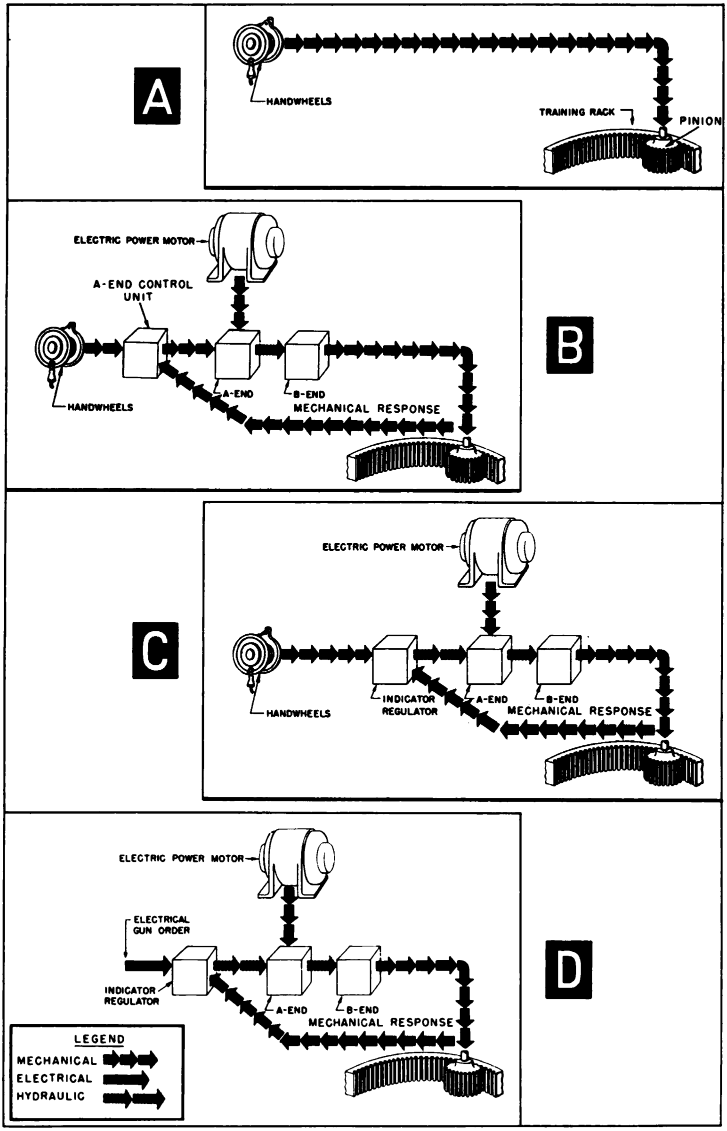


Figure 8–29.—Types of control on 5"/38 mounts. A. Manual. B. Hand. C. Local power. D. Automatic.

sensitive hydraulic valve system in the indicator-regulator is operated by double-speed SYNCHRO RECEIVERS which are driven by synchro transmitters in the director or computer. Both GE and Ford regulators contain separate hydraulic valve mechanisms for coarse and fine operation. The control loop is shown in figure 8–29D; mechanical response operates on the synchro stators to return them to correspondence (null position). Note that unlike the Amplidyne and YS&L control system, 5"/38 GE and Ford electrohydraulic power drive equipments use synchro receivers rather than synchro control transformers, and instead of electronic amplifiers, have hydraulic-mechanical "amplifiers." (These will be taken up in further detail in later courses in this series.)

5"/38 Crew Stations and Duties

To qualify as a GM 2, you must show that you can train 5"/38 battle station crews in operation, casualty procedures, and safety precautions. There isn't space in this course to give you the complete story on crew stations and operations; see the preceding course in this series and the OP's on the different types of 5"/38 gun mounts for details. But for a general review of the high spots look at the crew operations summary in the section on the 5"/54 Mk 39 mount further on in this chapter.

5"/38 Mount Casualties

Again, we can only hit the high spots. Remember that your job as Gunner's Mate is to KEEP THE GUN FIRING, so with the 5"/38 as with other guns, you should have a thorough knowledge of common casualties and their correction.

Most of the 5"/38 casualties during firing (other than power drive troubles) fall into four categories—power failure, breech mechanism casualties, or rammer casualties, and personnel errors. Power drive troubles are discussed in chapter 15. The others are taken up below.

For action on power failures you'll have to depend heavily on the responsible Electrician's Mate. But it's a good idea to learn the locations of the circuit breakers on all the motor controllers on the mount. Then you can restore current quickly in case of momentary overload. But don't try to go beyond that. If the circuit breaker opens a second time, go into manual, even for ramming. Never try electrical repairs except under the eye of an experienced Electrician's Mate, and with the permission of the gunnery officer or the responsible division officer.

Breech mechanism casualties are often caused by faulty adjustment, careless cleaning, or poor loading procedure. In these cases trouble should have been stopped before it started—meaning better maintenance and more drill for the loading crew. It's unwise to put too much reliance on the gun captain's ability to close the breech with his rawhide maul.

Rammer casualties may be due either to power failure (in which case the crew must ram by hand) or failure of the rammer mechanism. You probably haven't yet learned the hydraulic mechanism of the rammer, so you can deal with its malfunctions only under the immediate guidance of a GM1 or GMC. Malfunction of the external mechanical parts can be caused by damage, excessive wear, poor adjustment, or mishandling. This can also cause malfunction of the hydraulic components.

Personnel errors may occur in mount operation or in mount maintenance. They may be errors of omission, or errors of commission. Their results may be evident at once, or they may develop suddenly at a later time. It isn't possible even to try to enumerate them all here. But some more or less representative samples are mentioned below.

The brief list following is intended to cover only the immediate action you can take to deal with some of these types of casualties that may develop during training practice or firing. It's no substitute for the troubleshooting and repair operations detailed in OP's and elsewhere, nor does it cover all possible casualties.

CASUALTY. Breechblock fails to close immediately or completely.

1. *Possible cause.* Imperfect rammer adjustment, the spade being held against the case with rammer relief valve pressure.

   Immediate action. Move the control lever to withdraw. Drive plug home with maul, if necessary.

   Correction. Adjust rammer mechanism. Examine buffers on rammer crosshead and replace if necessary.

2. *Another possible cause.* Insufficient compression on breech operating spring.

   Immediate action. Drive plug home with maul.

   Correction. Set additional spring compression.

3. *Possible cause.* Defective cartridge case jamming breechblock.

   Immediate action (correction). Attempt to close breech with maul. If unsuccessful, extract defective case and set aside. (If gun is hot, work fast.) Reload with fresh case. To prevent recurrence, inspect cases to be sure the cork plug overhangs and protects the case lip, and make sure case is not bent or damaged.

4. *Possible cause.* Relief valve setting on rammer too low; rammer unable to complete ram stroke.

   Immediate action. Drive plug home with maul. Shift to hand ramming.

   Correction. Readjust relief valve setting.

5. *Possible cause.* Grit, foreign matter, or burs in grooves between breechblock and housing.

   Immediate action. Be sure there is no foreign matter that will fire the primer. Drive plug home with maul.

   Correction. Remove, clean, and oil the plug. Stone down the burs. To prevent further trouble, keep the plug and breechway clean.

6. *Possible cause.* Foreign object being rammed with the round. (Example: A drill primer has been known to fall into the tray and be rammed into the chamber.)

   Immediate action (correction). Extract object. To prevent a recurrence, inspect the gun and mount for such loose foreign objects before firing.

CASUALTY. Jammed load in tray. (Projectile or case jammed against face of breech, or up-ended, or thrown out of tray. Cartridge case generally damaged as a result.)

1. *Probable cause.* Personnel error. (Case loaded on top of projectile, or projectile atop case, or projectile not steadied in tray when loaded, or rammerman rammed too soon.)

   Immediate action. Remove ammunition and set aside for later inspection. Reload.

   Correction. More drill for crew.

CASUALTY. Hot case jams between gun platform and spade.

1. *Probable cause.* Personnel error (spademan failed to move case stop into position as gun elevated) or defective case stop.

   Immediate action. Depress gun. Hot-case man removes case. Resume loading.

   Correction. More drill (if personnel error) or repair case stop (if mechanical failure).

CASUALTY. Rammer motor cuts out after gun fires or other shock.

1. *Possible cause.* Spring pressure on stop button insufficient.

   Immediate action. Push starting button, and resume. If necessary, ram by hand.

   Correction. Replace stop button assembly, or adjust spring for greater pressure.

2. *Possible cause.* Defective relay in control box.

   Immediate action. As in No. 1 above.

   Correction. Replace defective relay.

CASUALTY. Ramming without charge, or ramming without projectile ("bale of hay") or cartridge case.

1. *Probable cause.* Personnel error.
2. *Immediate action.* Clear chamber, if necessary, and reload.
3. *Correction.* More drill.

CASUALTY. Rammer failure, perhaps accompanied by leaking oil, unusual noises, or other symptoms.

1. *Probable cause.* Hydraulic failure.

   Immediate action. Stop rammer motor, and ram by hand. If time and conditions permit, drain the oil from the rammer.

   Correction. Find the trouble, repair, and reset relief valve. (See the appropriate OP).

CASUALTY. Misfire.

1. *Possible cause.* Broken primer bridge. Probably the result of previous rough handling, or possibly originally defective.

   Immediate action. Fire by percussion.

2. *Possible cause.* Broken firing circuit (lead).

   Immediate action. Fire by percussion.

   Correction. Careful inspection before firing. See that firing leads are of ample length. Inspect all contact points. Replace if necessary.

3. *Possible cause.* Grounded firing circuit. (Faulty insulation either in firing lock or wiring.)

   Immediate action. Fire by percussion.

   Correction. Crew should test with megger after installing firing lock as part of preparation for firing. Clean or replace lock if necessary.

4. *Possible cause.* Personnel failure to squeeze key; or switch thrown to wrong position.

Immediate action. Shift to battery or percussion firing.
Correction. More drill.

CASUALTY. Misfire. (Percussion.)

1. *Possible cause.* Defective percussion firing linkage.
   Immediate action. Recock and continue attempts to fire. If necessary carry out hangfire procedure.
   Correction. Overhaul percussion firing linkage.
2. *Possible cause.* Defective primer.
   Immediate action. Same as No. 1 above. Carry out procedure according to *Safety Precautions* and OP 1591.

5"/38 Mount Characteristics by Mark and Mod.

Now that we've examined the 5"/38 mount in general, here is a summary of its features as they apply to the specific mounts that you can expect to encounter. For the most part, this summary does not take up the individual mods; its statements apply to the mounts in each current mark, but individual mods may differ in some details. OP references are shown for each mark.

5"/38 MARK 24. This single mount has four mods (0, 1, 6, 11), of which the most important is the Mod 11, installed as the main battery on some aircraft carriers. This mod is an open dual-purpose pedestal-type mount with General Electric-Northern electrohydraulic train and elevation power drives and GE elevation and train indicator-regulators. It has three types of control—manual, local, and automatic—and is equipped with an automatic fuze setter at the edge of the platform. The fuze setter is driven by its own indicator-regulator. For details, see OP 700.

5"/38 MARK 28. This mount has mods numbered 0 to 3. It is a twin dual-purpose enclosed base-ring type mount with Ford-Waterbury electrohydraulic power drives and indicator-regulators. Mods 0, 2, and 3, which weigh over 169,000 pounds, are designed for light cruiser installation. As with many 5-inch mounts intended for use with a director, this one has four types of control: manual, hand, local, and automatic. For details, see OP 805.

5"/38 MARK 30 (MODS FROM 0 TO 85). Single DP base-ring mount, open or enclosed, with or without projectile hoists (depending on whether the mount is installed over a handling room). Mounts without projectile hoists either have separate fuze setters on the mount, or are equipped with fuze wrenches so that the crew can set fuzes by hand. Some mods are equipped with Ford indicator-regulators and electrohydraulic power drive, but most of them (especially the later mods) are equipped with GE indicator-regulators and power-drive equipment. Some have hand control; most have only manual, local, and automatic. Some mods of open mounts, intended for installation on auxiliaries and merchant ships, have manual drive only. A couple of others, intended for similar installation, are equipped with electrohydraulic drives and have hand and manual control, but no local or automatic. The Mk 30 mounts are designed for installation on many types of combat vessels—especially DD's and DE's, but not CL's and BB's—and on auxiliaries and merchant vessels which mount 5-inch weapons. The OP reference is OP 735.

5"/38 MARK 32 (MODS 0 TO 12). Twin enclosed DP base-ring type with Ford indicator-regulators and Ford-Waterbury electrohydraulic drive. These mounts have four types of control—manual, hand, local, and automatic. All are, of course, equipped with ammunition hoists. They are designed for installation on larger combat ships—BB's, CV's, CL's, and some others. The various mods differ chiefly in details of shield weight and construction. See OP 805.

5"/38 MARK 37 (MODS 0 TO 14). Single open DP base-ring type intended for installation on auxiliaries and merchant vessels. They are therefore not equipped with indicator-regulators for automatic control. However, they do have electrohydraulic power drives (Northern) and can be operated in hand or manual control. Most mods are equipped with indicator-receivers, so that they can be operated in indicating control. All have fuze setters on the mount. See OP 868.

5"/38 MARK 38 (MODS 0 AND 1). Twin enclosed DP base-ring type with Ford indicator-regulators and Ford-Waterbury electrohydraulic drives. These mounts run lighter in weight than the Mk 32 series, chiefly because of lighter-weight shields, but otherwise their characteristics are quite similar. They are intended for installation on lighter combat and auxiliary craft—DD's and AG's. See OP 805.

5"/54 MOUNT MK 39

The Navy has two marks of 5"/54 mounts—the Mk 39 and the Mk 42. The Mk 39 closely resembles in construction and operation the 5"/38 mounts described above; the Mk 42 is a completely new design, and is covered in the section on new developments.

The Mk 39 5"/54 mount is an enclosed dual-purpose semiautomatic base-ring design developed primarily for carriers of the *Midway class.* In most of its features it resembles either twin or single 5"/38 mounts. For example, the breech and firing mechanism, slide, rammer, and so on differ only in minor details from the single 5"/38. The sight system is very like that of the twin mount, and it has a powder and a projectile hoist much like those of the twin.

But the Mk 39 does have some novel features. Its gun is longer by 14 calibers; the chamber, ammunition, and ballistics are different too. It fires semifixed ammunition (70-lb. projectile and 32-lb. case). Its horizontal range is about 26,000 yards and ceiling is 49,000 feet. The Amplidyne train and elevating drives function like those discussed elsewhere in this course, and may be operated in manual, local, or automatic. (The hoists, however, are electrohydraulic and closely resemble the 5"/38 types previously discussed.)

The novel constructional scheme is shown in figure 8–30A. The Mk 39 is built like a junior-size turret. There's no

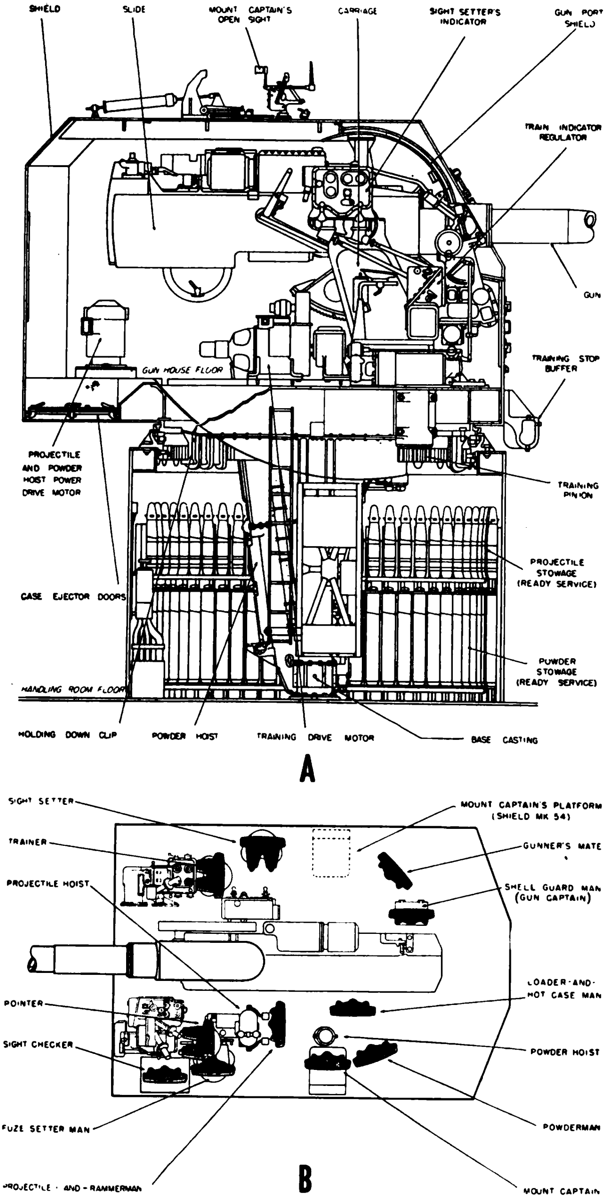


Figure 8–30.—5"/54 mount Mk 39. A. Longitudinal section, right side. B. Crew stations (gun house).

armored barbette, but the stand is supported by a circular foundation bulkhead, inside which is the upper handling room. Figure 8–30A also gives you some idea of the geography of the gun house and handling room levels. The Amplidyne equipment (except for the train and elevation drive motors) is located in a gun control room outside the mount.

The OP reference for the Mk 39 is OP 1027.

5-INCH MOUNT CREW STATIONS

Figure 8–30B shows the crew stations at the 5"/54 Mk 39 gun house level. The Mk 39 is like the 5"/38 mounts in crew arrangement and duties. Let's very briefly review them as typical of all 5-inch mounts except the Mk 42.

The mount captain is the command leader. He may man the station in the mount overhead, operating the mount captain's ring sight. A Gunner's Mate is the mount captain's principal assistant, and supervisor of gun operation. He assists in mount casting loose and securing operations, reports readiness to fire to the mount captain, directs and assists in cleaning and securing gun and equipment, and serves as the troubleshooter and chief maintenance man. The pointer is responsible for setting up his sight, checking the firing mechanism, and checking and operating the sight and (when not in automatic) the elevating gear. The trainer does similarly for his part of the mount. The sight setter receives and sets sight deflection and sight angle. The fuze setter tests the fuze-setting mechanism, and operates it when not in automatic. The projectile-and-rammerman assists in testing the projectile hoist, checks and operates the rammer, and loads projectiles. The gun captain operates the rammer spade, and checks the loading operation details. He also operates the rammer spade release. The powderman takes the cases out of hoist and passes them to the loader-hot-case man. He puts the cases in the slide, and picks up extracted cases that are not automatically ejected and casts them through the ejector hatch. He also checks the counterrecoil system and assists in rammer and firing tests.

In addition to these ten men in the gun house, there are six in the upper handling room (not diagrammed). Two powdermen keep the powder hoist supplied, two projectilemen do the same for the projectile hoists, and two others operate scuttles through which ammunition is passed from the magazines.

So much for this quick review. The Mk 39 crew setup is much like that on 5"/38 mounts; the general setup in all is basically the same, with variations in detail (depending on the number of guns and hoists).

NEW DEVELOPMENTS IN GUN MOUNTS

In this chapter we've discussed the gun mounts currently in wide service in the Fleet. But there are two others that you, perhaps, haven't seen yet, though you'll see more of them as time goes on. One is a 3"/70, the other a 5"/54, and both are radically different from their contemporaries. Most details on both are still classified as of this writing, so what can be said about them in this book is strictly limited.

3"/70 Mount Mk 37 and Mods

The 3-inch mount Mk 37 is a twin dual-purpose shield-enclosed base-ring type mount, firing fixed electric-primed ammunition. An exterior view is shown in figure 8–31. It has two 3"/70 water-cooled guns mounted in a single slide. Each gun can be fired separately, or both can be used simultaneously, either in single fire or automatically in continuous bursts. Each gun has its own mechanized ammunition-handling system. Ammunition is rammed during counterrecoil, and the empty case is ejected during recoil. Critical rubbing surfaces are lubricated automatically to reduce wear. The breech mechanism is a sliding-wedge type, but the breechblock is unique (for a naval gun) because it oscillates horizontally. The pre-

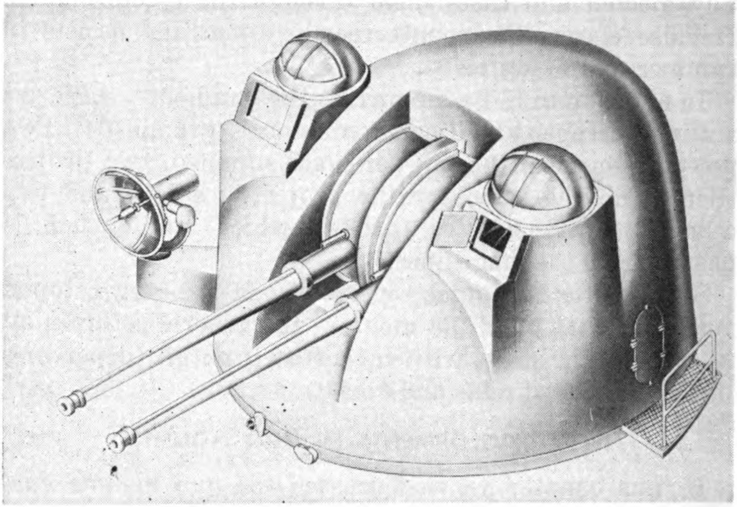


Figure 8–31.—3"/70 Mount Mk 37. Exterior.

scribed crew in the mount at the present includes the mount captain, surface gunner, right and left gun captains, and (optional) Gunner's Mate. Eleven more men are in the ammunition-handling and reloading operation, though the mount can go into operation and fire for some time without them if necessary.

For further information on the Mk 37 and its mods, see OP 1718 when it becomes available.

5"/54 Mount Mk 42 Mods 1 to 6

The 5"/54 mounts Mk 42 mods 1 to 6 are dual-purpose single enclosed mounts, base-ring type, fitted with automatic ammunition feed mechanisms that permit them to deliver rapid automatic fire at high speeds against air or surface targets. All mods of the Mk 42 are fundamentally similar; the modifications adapt the mount to suit specific installation requirements at various locations aboard ship. The Mk 42's exterior is illustrated in figure 8–32.

Unlike the Amplidyne-driven Mk 39, the 5"/54 mount

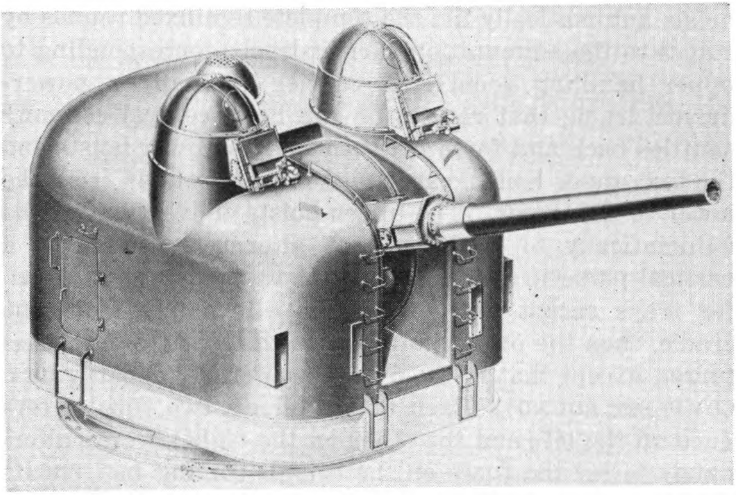


Figure 8–32.—5"/54 Mount Mk 42. Exterior.

Mk 42 is driven by electrohydraulic power units. It can be operated in local or automatic control, but there is no hand control, and manual operation is only for adjustment while servicing.

The gun housing, slide, and breech mechanism are quite different from the semiautomatic 5"/54 Mk 39 and 5"/38 designs. The housing moves in recoil and counterrecoil in the slide on roller bearings. The vertical sliding-wedge breechblock and the extractors are hydraulically actuated. The counterrecoil system has two cylinders on the left side of the slide; the recoil cylinders are arranged symmetrically on either side.

With its novel ammunition feed system, the single 5"/54 gun has a higher normal firing rate than a twin 5"/38 operating full blast on both barrels. In the mount's lower handling room are two cylindrical electrohydraulic-operated loading drums that store complete rounds of ammunition, and feed them to the two lower hoists as needed. Loading these drums is the only manual operation needed in feeding ammunition to the gun. The lower hoists automatically lift the complete semifixed rounds by stages to the ammunition carrier level (corresponding to upper handling room). A carrier (actually a power-driven frame that rotates on the hoist central column) shuttles back and forth between the two lower hoists and the two upper hoists, carrying complete rounds from the lower to the upper. The upper hoists deliver the rounds automatically to cradles which alternately swing in a vertical plane to lift the rounds to the slide. Slide transfer trays accept the ammunition alternately from one cradle, then the other (much as in the 8"/55 *Salem* class turret, except that in the 5"/54 each cradle is carrying a COMPLETE ROUND). Each of the slide's two fuze setters (one on the left and the other on the right) works alternately to set the fuzes on the rounds coming in from its side. Each tray, when loaded, swings inboard on the slide to align with the bore; the round is rammed, the rammer retracts, the tray swings out of the way, and the gun fires.

In this course we can't give you more than this very brief glimpse at the Mk 42. If you want to learn more, see OP 1764, and get to see the training films on it.

QUIZ

In each of the following, select the one BEST answer.

1. The part of the 20-mm gun mount in which the gun is placed is the
   a. pedestal
   b. carriage
   c. cradle
   d. receiver

2. In the 20-mm gun crew, deflection or elevation spots are introduced by the
   a. first loader
   b. gunner
   c. range setter
   d. spotter.

3. Assume your hot 20-mm gun has misfired. Which of the following MUST you do, regardless of the other measures you may take?
   a. Douse the barrel and receiver with water
   b. Eject the misfired round immediately
   c. Point the gun in a safe direction
   d. Remove the barrel and immerse it in water without delay

4. See how well you know your 40-mm mounts. Which one of the following features applies to 40-mm single mounts but NOT to twins or quads?
   a. External counterrecoil springs
   b. Hydraulic recoil brakes
   c. Electrohydraulic power drives
   d. Air-cooled gun barrels

5. On 40-mm mounts, the method of fire (manual, local, or director) is determined by
   a. setting a firing selector switch
   b. depressing the firing pedal
   c. engaging or disengaging the firing clutch
   d. energizing or deenergizing a solenoid coil

6. In each gun of a 40-mm mount, when the foot-firing pedal is depressed as far as it will go,
   a. the firing clutch is engaged and the firing motor operates the trigger mechanism
   b. the firing circuit is closed, energizing the solenoid whose armature operates the firing gun through a linkage.
   c. the connecting linkage moves the sear, which releases the firing pin so that it strikes the primer

d. the connecting linkage pushes the firing plunger into the gun trunnion, causing the trigger mechanism to release the rammer

7. On Mk 2 40-mm mounts the lag meter shows
   a. rate of change of gun order
   b. rate of gun mount movement
   c. whether the mount is in automatic or local
   d. error between gun order and gun position

8. On Mk 2 40-mm mounts, when the power selector lever is set so that the transfer valve is open, the power interlock switch is
   a. closed
   b. open
   c. set to prevent starting the power motor
   d. set to permit local control by joystick

9. Which of the following components is common to both the Amplidyne power drive and the YS&L system?
   a. Drive motor
   b. Generator
   c. Stroke motor
   d. Amplifier

10. In a 40-mm quad mount, each gun is served by how many loaders?
   a. 1
   b. 2
   c. 4
   d. 8

11. If a 40-mm gun has a stoppage with a round in the chamber and breech fully closed, which of the following causes is LEAST likely to be responsible?
   a. Defective primer
   b. Twisted crankshaft
   c. Weak breech closing spring
   d. Broken firing pin

12. If a 40-mm quits firing with breechblock down, chamber empty, and no round on the tray, the MOST PROBABLE cause is:
   a. Twisted crankshaft
   b. Weak or broken breech closing spring
   c. Failure of loader to feed
   d. Broken rammer spring

13. See how well you know your 3"/50 RF mounts. Which one of the following mods of the Mk 33 twin is an ENCLOSED mount?
   a. Mod 2
   b. Mod 4

c. Mod 6
d. Mod 8

14. In the 3″/50 loader, the gates open to deliver the ammunition round to the
a. tray
b. chamber
c. shell feed
d. sprockets

15. In the 3-inch loader, how many operating cycles must the loader go through before a round is deposited in the tray? (Don't count the cycle during which the tray actually receives the round.)
a. 1
b. 2
c. 3
d. 4

16. On 3″/50 RF mounts, which of the following controls have NO effect on the operations of the left gun layer?
a. Local-automatic selector
b. Power drive controls
c. Firing selector
d. Sight setter

17. In a 5″/38 powder hoist, one of the following circumstances has NO effect on whether or not the hoist cycle is capable of starting. Which one is it?
a. Cartridge case is loaded base up
b. Cartridge case is loaded into hoist lower end
c. Hoist lower doors are closed
d. Hoist upper end is empty

18. In normal operation of a 5-inch projectile hoist, when is the flight fuze-setter sprocket disengaged from the fuze-setting chain?
a. When the fuze setter is being cranked in local control
b. When the flight is being hoisted
c. When the flight is being lowered
d. Never

19. In the Mk 31 sight mechanism (5″/38 single mount) the sight driving pinion rotates with respect to the sight driving gear when
a. the gun is elevated or depressed
b. the sight angle handcrank is turned
c. the compensator screw introduces its correction
d. the driving pinion bracket rotates with the gun trunnion

20. The purpose of the compensator mechanism in the Mk 31 sight mechanism is to
    a. prevent the housing from "walking" around the bevel gear it engages, when the gun is elevated or depressed
    b. keep the "walking" of the housing gear around the bevel gear as the gun is elevated or depressed from being transmitted to the sight prism
    c. shift the sight prisms just enough to compensate for error introduced as the housing gear "walks" around the bevel gear when the gun is elevated or depressed
    d. transmit trunnion motion to the sight angle dial so that the dial will indicate the change in sight angle introduced by the "walking" of the housing gear around the bevel gear as the gun is elevated or depressed

21. Which of the following components of the Mk 36 (twin 5"/38 mount) sight mechanism is NOT part of the Mk 31 (single 5"/38 mount) sight mechanism?
    a. Range dial
    b. Differential
    c. Checker's telescope
    d. Movable-prism telescope

22. In which of the following types of control possible on 5"/38 mounts does the trainer or pointer control mount movement through the indicator-regulator?
    a. Automatic
    b. Local power
    c. Hand
    d. Manual

23. In 5"/38 breech mechanism, a weak breech-operating spring can cause
    a. failure of breech to open on counterrecoil
    b. sluggish extraction
    c. failure of breech to close completely
    d. salvo latch malfunctioning

CHAPTER 9

BREECH MECHANISMS

INTRODUCTION

In this chapter we'll take up the breech mechanisms of naval guns larger than machine guns, including the 3"/50, 5"/38, and 5"/54. We won't go into detail on breech mechanisms used in turret guns, because they're beyond the scope of this course; machine gun and small-arms breech mechanisms are taken up elsewhere in this course and in the GM3 course. Firing mechanisms are taken up in chapter 10.

A REVIEW OF BREECH MECHANISM PRINCIPLES

Before we discuss any breech mechanisms in detail, let's very briefly review the purpose they serve and the main principles of the different types.

Every gun breech mechanism must:

1. Stay closed and maintain a seal against the pressure of propellent gas.
2. Open and close rapidly to permit quick loading and (in case guns) extraction.

These are minimum requirements. Most modern breech mechanisms designs for naval guns also provide for performing, at least in part, ramming and extraction. All present gun breech mechanisms also incorporate essential parts of the firing system. However, in this course firing mechanisms and systems are taken up in another chapter, and we won't go into them here.

Fundamental Types of Gun Breech Mechanisms

The three general types of breech mechanisms used in modern naval guns are the:

1. INTERRUPTED-SCREW type.
2. SLIDING-WEDGE type.
3. BOLT type.

The interrupted-screw breech mechanism uses threads on the plug to engage mating threads in the gun screw box; cutaway sectors on plug and screw box permit complete insertion of the plug before the plug is turned to engage its threads with those of the screw box. To increase the amount of threaded surface that takes up the stresses imposed by propellent gas pressure, the cylindrical surfaces of plug and screw box are arranged in STEPS. This stepped-thread or WELIN mechanism is the standard type used in all bag-ammunition naval turret guns. Interrupted-screw breech mechanisms are used also in depth-charge projectors, and the principle has a number of other applications that we won't go into here. Figure 9–1 shows clearly the principle as it applies to

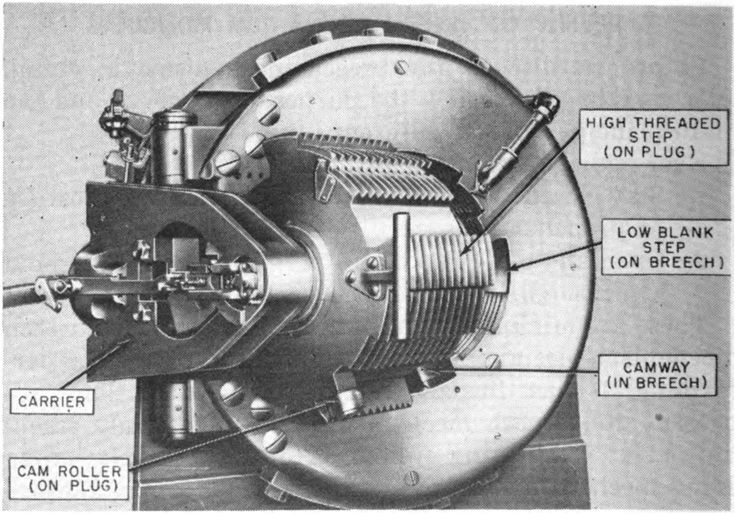


Figure 9–1.—Interrupted-screw breech mechanism for 14-inch gun.

bag-gun breech mechanisms, though the gun illustrated is of a type no longer in active service.

The principle of the sliding-wedge breech mechanism is illustrated in figure 9–2, which shows a grooved breechblock which can slide up and down, and the mating grooves in the housing which force the breechblock to push the cartridge case all the way home into the chamber as it closes. It does not show the extractor mechanism which is a part of any breech mechanism that handles case ammunition. (The figure does not represent any specific gun mechanism.)

In 40-mm, 3-inch, and most 5-inch case gun mechanisms the extractor is mechanically connected to and operated by the breechblock. In one mark of 5"/54 and in 6-inch and 8-inch rapid-fire (RF) turret guns, which fire semifixed case ammunition, the extractors are operated by separate hydraulically powered mechanisms. Except for one classified type of 3-inch gun, sliding-wedge breechblocks in naval guns move vertically with respect to the

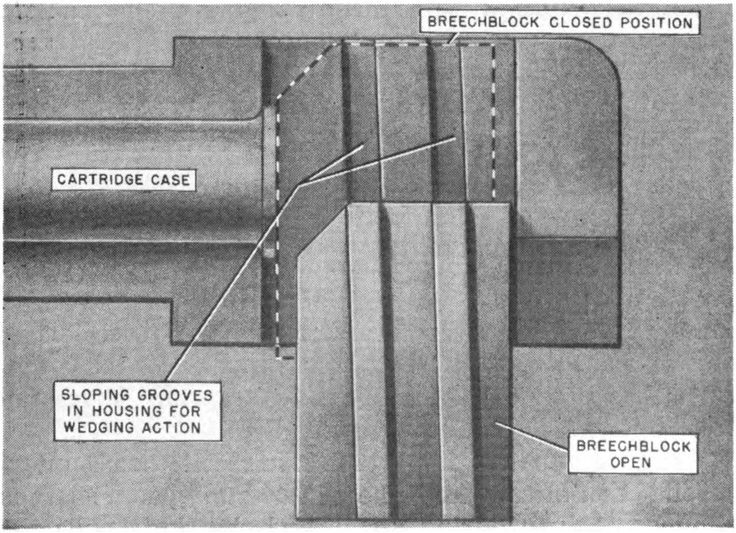

BREECHBLOCK CLOSED POSITION
CARTRIDGE CASE
SLOPING GROOVES IN HOUSING FOR WEDGING ACTION
BREECHBLOCK OPEN

Figure 9–2.—Principle of the sliding-wedge breechblock.

bore axis; in the exception (which is not within the scope of this chapter) the breechblock moves laterally.

The bolt type of breech mechanism has a breechblock which moves in line with the bore axis—to the rear to open the chamber, forward to close it. It's used not only in small arms but also in all Navy machine guns 20-mm and smaller. You're already familiar with the principle and a number of applications (see chapters 13 and 14, and the previous course in this series), so no further discussion here is necessary.

In this chapter we focus on several important applications of the sliding-wedge breech mechanism. We'll take up in some detail the time-tested (and still the commonest in the Fleet) 5"/38 and 5"/54 semiautomatic type, go on to its little brother, the 3"/50, and wind up with a brief review of its hydraulically operated cousin, the new 5"/54.

FUNDAMENTALS OF TYPICAL SLIDING-WEDGE BREECH MECHANISMS

Before we begin with the 5"/38 breech mechanism that we're going to study as the prototype of such mechanisms, let's take a quick look at some simplified fundamentals of sliding-wedge breech mechanisms. Figure 9–3A shows their geography, and figure 9–3B illustrates how they function.

In figure 9–3A the breechblock is just beginning to close, and the breechblock is on its way up. Its upward movement is triggered by the pull that the forward-moving cartridge gives to the extractors. In 3"/50 and 5"/38 semiautomatic guns the extractors lock the breechblock down (open); when the extractors' upper ends move forward, the breechblock unlocks and a spring drives the block up.

When the gun fires, it moves first in recoil, then counterrecoil. You already know how in 40-mm guns a shaft is cammed to turn during recoil, and the shaft pulls the block down against the thrust of a spring. In 3"/50 and

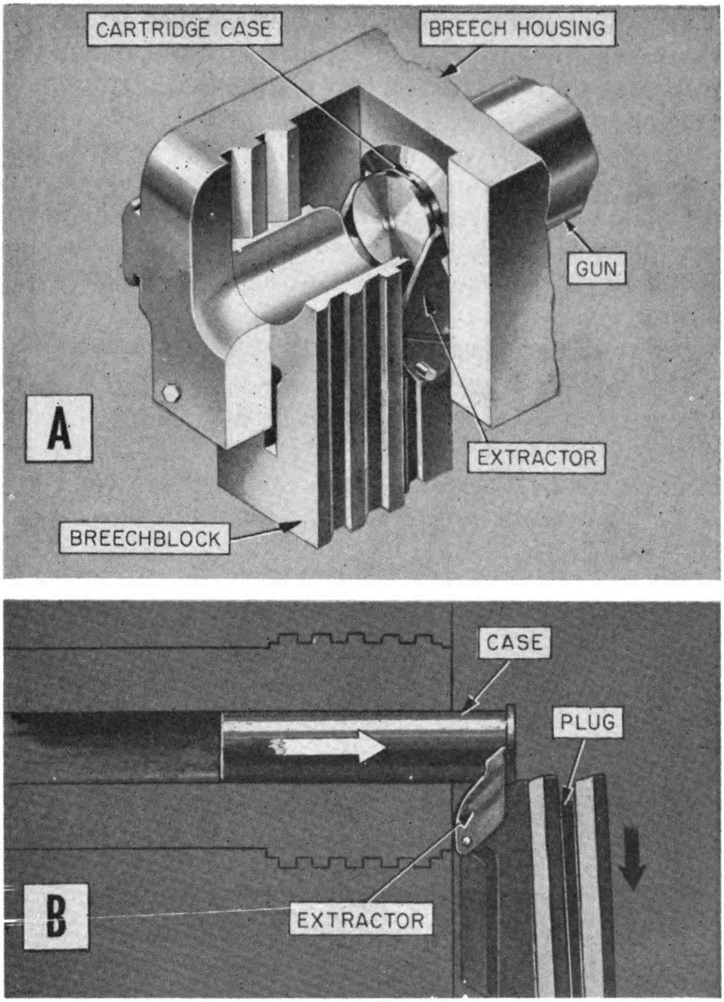


Figure 9–3.—Sliding-wedge breech mechanism. A. General features. B. Principle of extraction.

5"/38 guns the mechanical details are different, and the breechblock goes down during COUNTERRECOIL, not recoil, but the principle is similar. The effect is shown in figure 9–3B; the extractor upper ends are cammed to the rear (notice that instead of being hinged as in the 40-mm they rock back on their curved forward edges) to extract the fired case.

In hydraulically operated sliding-wedge breech mechanisms, the extractors are driven by a separate hydraulic cylinder, but even here they are triggered by the beginning of breechblock opening movement.

Now let's look more closely at a 5"/38 breech mechanism.

BREECH OPERATING MECHANISM (5"/38)

Figure 9–4 shows the basic components of the breech operating mechanism as you would see them if the slide and housing were clear glass instead of steel. The breechblock is closed. Under the breechblock and linked to it is the OPERATING SHAFT, which is coupled to the OPERATING SPRING.

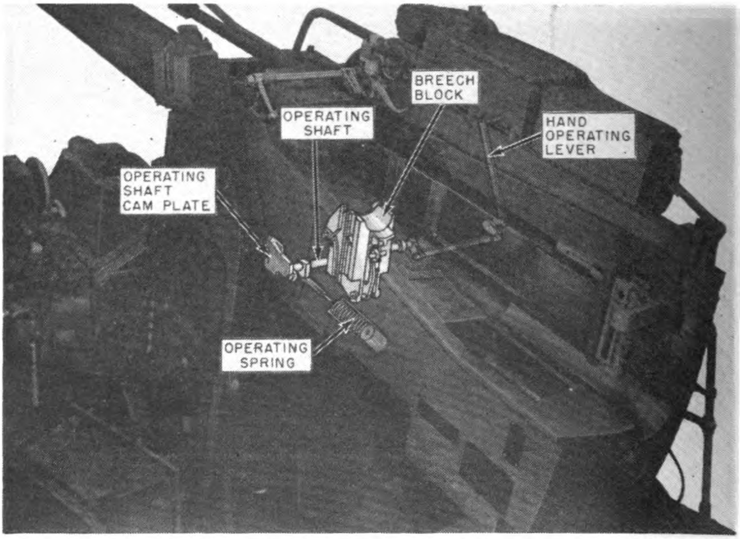


Figure 9–4.—Breech operating mechanism (5"/38).

The right end of the operating shaft is linked to the HAND OPERATING LEVER on the right side of the slide. At the left end of the operating shaft are the OPERATING SHAFT CRANK, and the OPERATING SHAFT CAM PLATE.

NOTE: We are looking at a single mount here. The right-hand gun of a twin mount is set up similarly, but in the left-hand gun most of these parts are of opposite hand.

A crank arm on the operating shaft is linked to the breechblock by two bearing blocks (not visible in fig. 9–4) that slide in ways in the breechblock. When the arm rotates, the breechblock moves up or down (depending

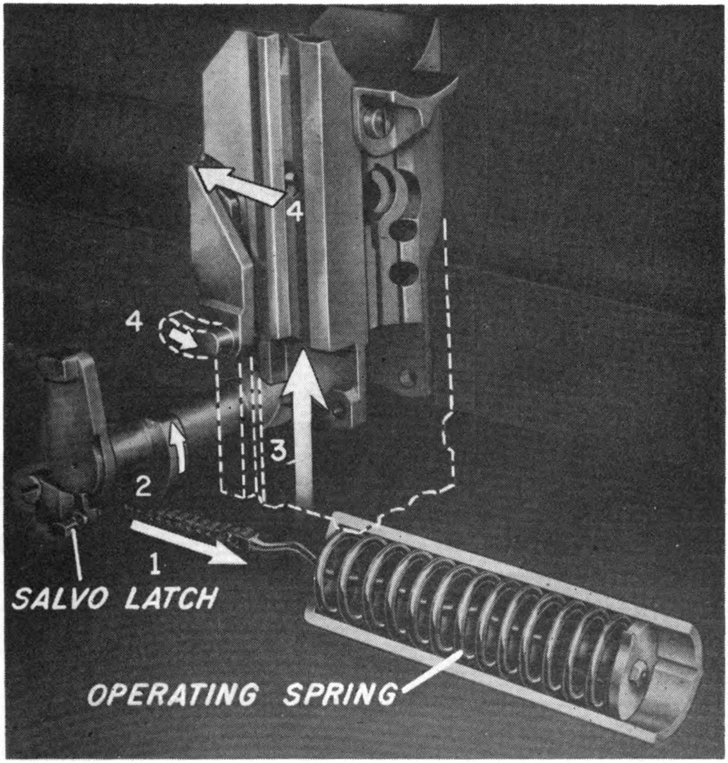


Figure 9–5.—Motions of breech mechanism components (5"/38).

on direction of rotation) in the breechway. The shaft rotates to lower the block either when the hand operating lever on its right is operated while the gun is in battery, or when the crank on its left end is cammed by an OPERATING SHAFT CAM PLATE as the housing returns to battery after firing. In either case, this rotation compresses the OPERATING SPRING, which is linked to the operating shaft by a chain. As you remember, the extractors lock the block down until the cartridge case being rammed into the chamber pulls them forward (or they may be unlocked manually by a special tool). In either case, spring thrust pulls the block up, and it's locked closed by the SALVO LATCH (figs. 9–5 and 9–10).

All these movements can be traced out in figure 9–5. The operating spring pulls (arrow No. 1), the shaft turns (2), the breechblock rises (3), and the extractors are cammed by the inner lug slot in the block (4). All these movements, naturally, reverse when the shaft is turned (either automatically or by the hand operating lever) in the opposite direction. The cam plate has been omitted from figure 9–5 for clarity.

Now let's follow the functioning cycle of the mechanism. As we watch it go through its paces, we'll look first at the breechblock and extractors.

Functioning of Breechblock and Extractors
(5"/38 Breech Mechanism)

Let's begin with the breech open. The breechblock is locked down and the operating shaft crank is under the cam plate. Figure 9–6A shows this condition.

For the moment, disregard the rammer spade and cartridge case in the figure, but notice how the extractors (only one is shown) lock the breechblock down. The breechblock is constantly under the upward thrust of the breech operating spring (working through the operating shaft). Each extractor has at its bottom two cylindrical lugs. The outer lug (solid circle in fig. 9–6A) is under the

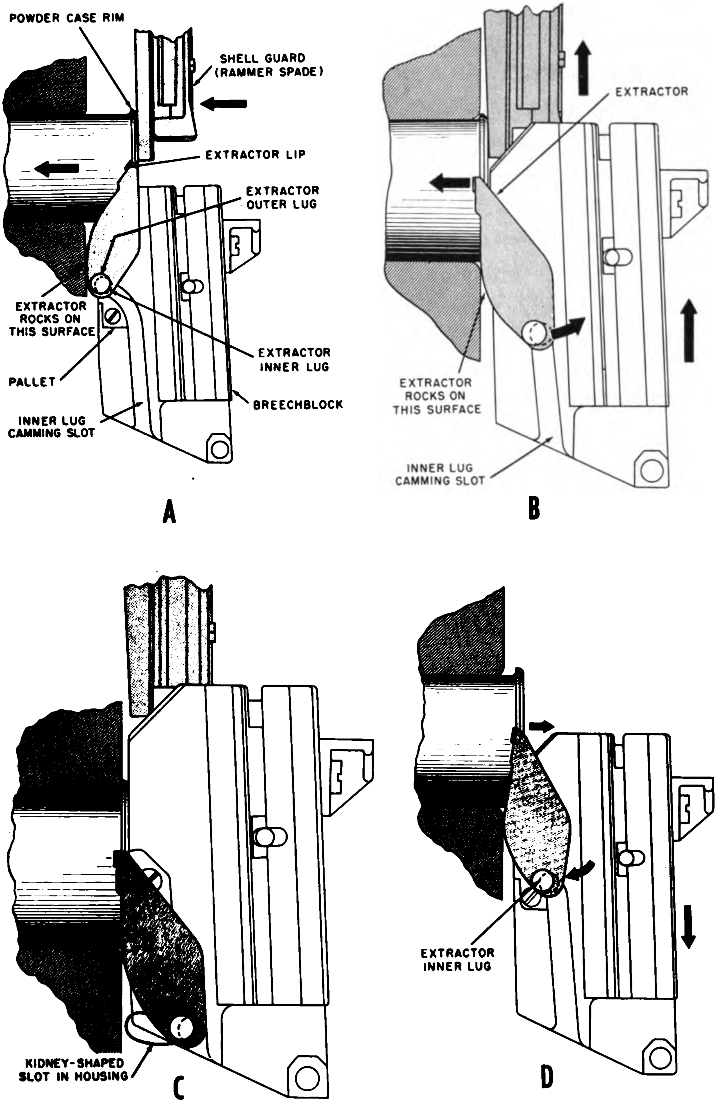


Figure 9–6.—5"/38 breech mechanism; breechblock and extractor action. A. Powder case rim engaging extractor lip; breechblock open. B. Powder. case rammed; breechblock rising to wedge case. C. Breechblock in closed position; ready to fire. D. Breech opening; beginning of extraction.

constant forward thrust of a spring-loaded plunger (not shown). (As the extractor works back and forth, this outer lug oscillates in a small arc in a kidney-shaped slot in the housing, sketched in fig. 9–6C.) Now look at the inner lug (dotted circle). This engages a long camming slot in the breechblock. At the top of the slot is a small flat-topped PALLET of hardened metal. When the breechblock is in open (down) position, its upward thrust forces the pallets against the inner lugs of the extractors. Both because the pallet tops are flat, and because of the plunger spring forward thrust on the outer lugs, the inner lug of each extractor remains seated on its pallet, locking the breechblock down so long as the extractors are otherwise undisturbed.

Now let's put the rammer spade and powder case back into the picture. The rammer pushes the case forward. The powder case rim pulls the extractors forward. This disengages the extractor inner lugs from the pallets. The

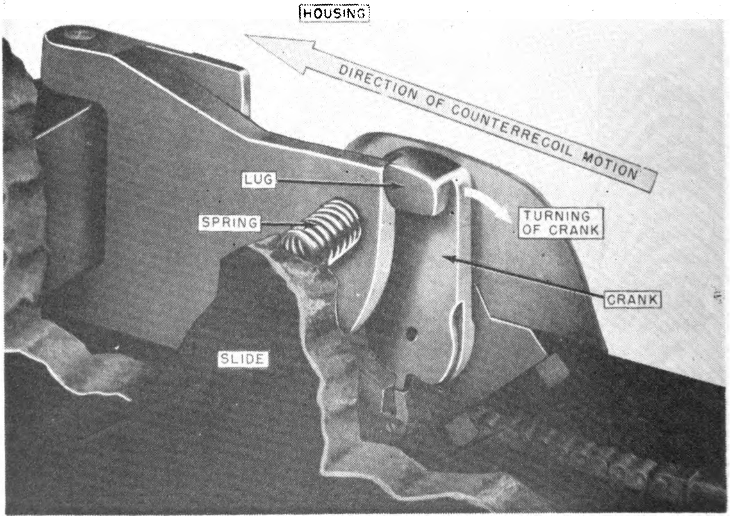


Figure 9–7.—5"/38 breech mechanism. Cam plate and operating shaft crank action during counterrecoil.

breechblock unlocks, and begins to rise. Figure 9–6B shows the breechblock up about halfway, pushing the rammer spade up, and the extractors rocking forward.

In figure 9–6C the breechblock has closed and locked, and the gun is ready to fire. The extractor lip is fully forward, nested in its cavity in the housing. The rammer spade is pushed all the way up.

Between figures 9–6C and 9–6D the gun has fired. The housing and gun barrel have moved aft in recoil, and have almost completed their forward (counterrecoil) movement to battery. The breechblock automatically begins to move downward, and the inner lug slot pushes the extractor inner lug forward. As a result, the extractor lip begins to rock backward, pulling the cartridge case rim with it. Arrows show how the various parts move. The extractors flip the cartridge case to the rear. When the block is fully down, the extractor inner lugs lock against the pallets, holding the block open, as it was at the start of the cycle.

Functioning of Cam Plate and Shaft Crank (5"/38 Breech Mechanism)

Now let's follow the other parts of the breech mechanism during this cycle. We've already seen that the breechblock is LIFTED automatically whenever the extractors' upper ends are pushed forward. The breech operating spring does this by rotating the operating shaft. The block is LOWERED by action of the operating shaft cam plate. This is a spring-loaded flat plate hinged to the inner surface of the left side of the slide. Figure 9–7 shows the housing moving forward in counterrecoil. The breechblock is up, as shown by the erect position of the operating shaft crank. When the lug on the crank meets the cam plate, it forces the crank to rotate. This moves the block down, operating the extractors, and causing them to lock the block open.

In recoil movement the lug merely pushes the cam plate back against its spring as it goes by, and the crank does not turn.

Note that the cam plate functions only to open the breech during counterrecoil. It does not hold the breech open; the extractors do that. A clearance cut in the inner side of the cam plate allows the crank to turn when the breechblock rises while the housing is in battery.

A cam plate retractor just under the slide can be set to "S" (single fire) to hold the cam plate against the slide so that it will not cam the breech open as the housing counterrecoils. This is necessary if some mechanical failure (such as a broken operating spring or chain) makes it inadvisable to have the breechblock open automatically. The cam plate retractor normally is set at "A" (automatic), where it functions to operate the breech mechanism in the way described.

Hand Operation of the 5"/38 Breech Mechanism

There are times when you operate the 5"/38 breech mechanism by hand. You do that when something goes wrong—if the operating spring or chain should break, for instance. And there are routine occasions for hand operation too—when you open the breech for the first round to be fired, and for inspection, cleaning, or boresighting. You use the HAND OPERATING LEVER, which will raise or lower the plug when the gun is in battery. Pulling the lever to the rear opens the plug.

CAUTION: After you've opened the breech, return the lever to breech closed (stowed) position where it is locked in place by the lever latch. If the lever is left to the rear, the rising breechblock will make it slam forward, and this can be rough on any part of your anatomy that may be in its path.

To see its working parts, look at figure 9–8, which shows the hand operating linkage as it is mounted on the right side of the slide, and in particular shows in detail the sliding latch, the lever that sets the sliding latch, the

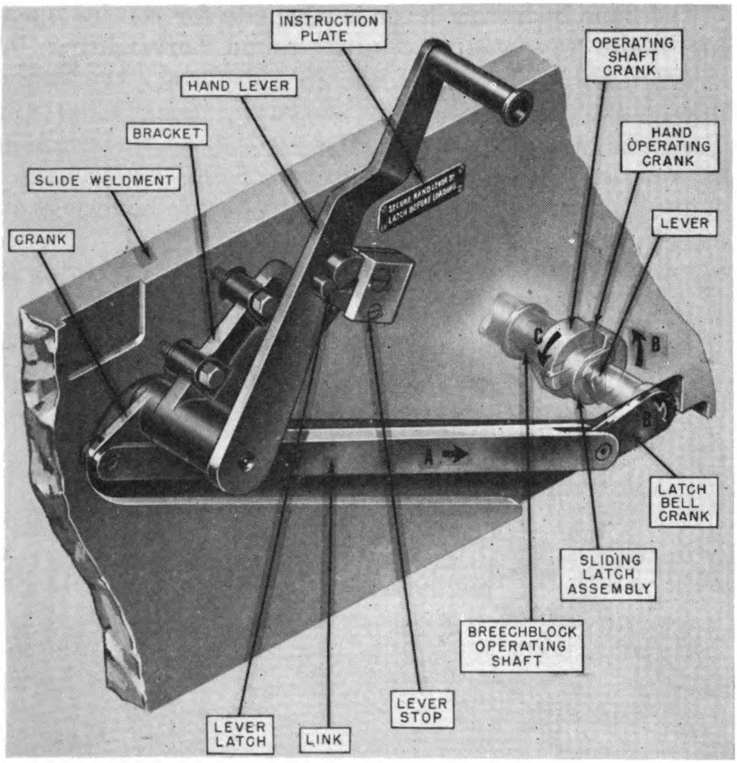


Figure 9–8.—5"/38 breech mechanism. Hand operating linkage.

operating shaft crank on the operating shaft, and the hand operating crank which is part of the latch bell crank.

When you pull the hand lever back (to lower the breechblock) the link moves down (arrow A), and turns the latch crank and the hand operating crank (arrow B). The crank in turn pushes the operating shaft crank in the same direction (arrow C), thus lowering the block. Once the block is down, the extractors lock it open.

When you return the hand operating lever to stowed position, the hand operating crank doesn't engage anything, and the linkage moves in "free wheeling."

The hand operating lever is adequate for routine opening of the breech for the initial round, boresighting, inspection, etc. However, there are times when the breech must be not only opened but CLOSED by hand. That's an emergency measure, which might be caused by failure of the operating spring, for example. To do this you set a SLIDING LATCH—a small metal block in the hand operating crank at the right end of the operating shaft. Figure 9–9A shows the latch, and the lever used for operating it, with the latch disengaged. Arrow 1 shows how the operating shaft moves in breech opening. Figure 9–9B shows the sliding latch engaged, and arrows 2 show how the hand operating linkage and the operating shaft turn when the breechblock is raised by the hand lever.

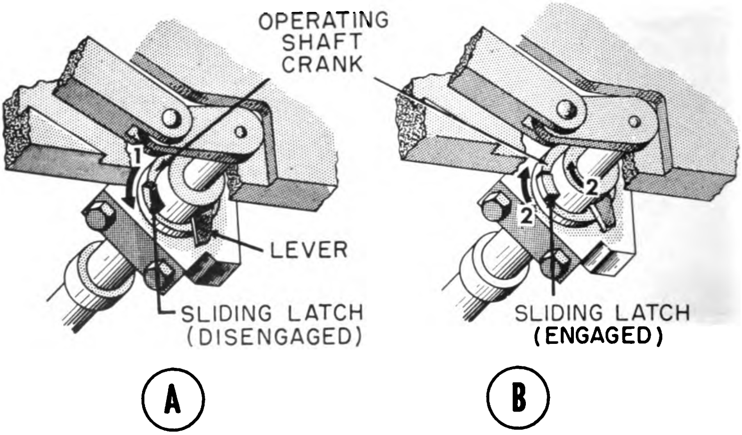


Figure 9–9.—5"/38 breech mechanism. Function of sliding latch in hand operating mechanism.

5-inch Breech Mechanism Safety Devices: Salvo Latch and Gas Ejector

SALVO LATCH. The salvo latch is, as you remember from the preceding course in this series, a safety device intended to protect the crew from unnoticed hangfires.

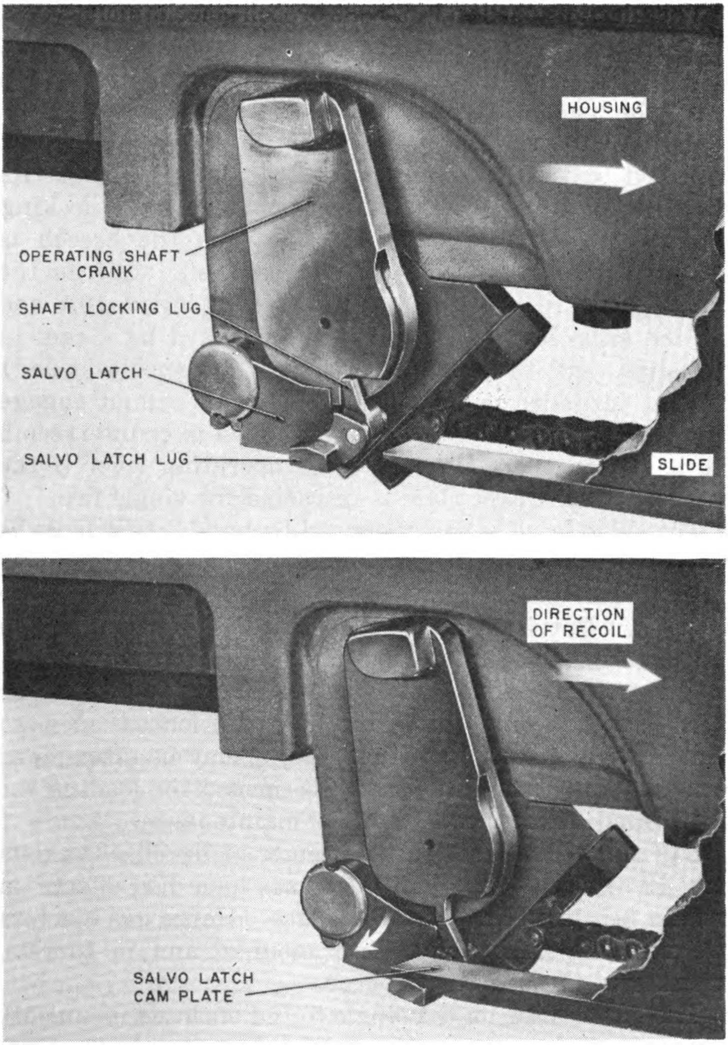


Figure 9–10.—5"/38 breech mechanism. Salvo latch functioning.

It does this by preventing ACCIDENTAL opening of the breech if the propelling charge has failed to fire.

The design used on 5"/38 breech mechanisms is a POSITIVE type (in contrast to the now obsolete INERTIA type) which is automatically opened by camming action when the housing recoils.

The salvo latch (fig. 9–10) is a spring-loaded assembly mounted under the operating shaft in the housing. As shown in figure 9–10A, its catch engages a shaft locking lug in the operating shaft crank when the breech is closed, and prevents the crank's rotation. But as the housing moves in recoil (white arrow in fig. 9–10A and B) the salvo latch lug is forced downward by a cam in the slide, and the catch (which is also spring-loaded) springs in under the crank lug so that it cannot engage the lug. The breech is now free to open in counterrecoil. Or it can be opened by the hand operating lever if the operating shaft cam plate is retracted for single fire.

The salvo latch is easily opened by hand. Just pull the salvo latch down until its catch snaps in under the operating crank shaft lug. The breechblock can then be lowered. But it shouldn't be necessary to remind you NEVER to disengage the salvo latch as a routine between rounds, except after prescribed misfire procedure. For drill purposes only, the latch may be locked open so that it won't function. Otherwise, it may be disengaged manually only when the breech is opened for loading the first round, for inspection, or for maintenance.

GAS EJECTOR. Although the danger of flarebacks exists only in bag-type guns, powder gases have bad effects on human beings in any enclosed space. Hence gas ejectors are fitted to guns in enclosed mounts, and in turrets, whether of the bag or case type.

The gas ejector on the single 5"/54 enclosed mount Mk 39 is a typical specimen (fig. 9–11.) The gas ejector automatically goes into action when the breech opens, blowing air from the ship's supply through nozzles in the breechway. This drives the gases outward through the bore.

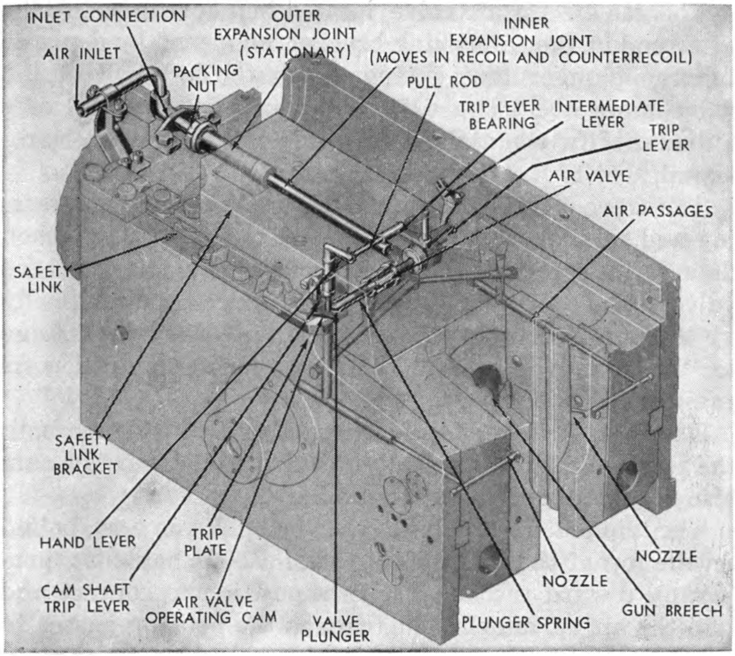


Figure 9–11.—5"/54 breech mechanism. Gas ejector.

Air flow is controlled by a valve located in the safety link bracket. The system is designed to operate either automatically or manually.

The controlling mechanism of the gas ejector is also located in the safety link bracket. It's interlocked with the rammer mounted on the slide. The air supply piping is attached to the carriage and slide with swivel joints to provide for movement of the mount in training and elevating. The air supply passes from slide to housing through a telescoping expansion joint, so that the ejector remains connected during recoil movement. The required normal gas ejecting pressure in this mount is 200 psi; estimated free air demand is 2.5 cubic feet per shot for automatic fire. In single-round fire with manual valve closing, air consumption is greater.

The gas ejector air valve, located in a bore crossing the after end of the safety link bracket, is opened by depressing the plunger that extends from the left end of the valve assembly. The valve is spring-loaded. It closes automatically when the pressure on the plunger is released.

The valve operating cam operates the valve by depressing and releasing the plunger. The cam has two notched detents, corresponding to open and closed positions of the valve. The valve cam is normally opened automatically by the trip plate (in counterrecoil) and closed by linkage to the rammer control lever (when ammunition is rammed).

The valve is linked to the rammer control lever through the trip levers, pull rod, and intermediate lever. The cam also may be operated by a hand lever.

The trip plate is a flat, hook-shaped plate of steel, bolted on the top of the left side of the slide. It has a lug projecting toward the housing in a position to contact and trip the air valve operating cam as the housing passes in counterrecoil. Thus it causes the air valve to open in counterrecoil.

Let us trace the route of the air through the gas ejector. From the air inlet (which leads from a swivel joint on the trunnion, not shown in the figure) the air goes through the expansion joint directly to the air valve chamber. When the valve is open, air flows through a passage in the valve housing to a vertical bore in the top surface of the gun housing. From this bore a series of drilled holes extends through the housing to two nozzles in the breechblock guides. These nozzles direct the air to the center of the gun bore.

Now let's follow through on gas ejector operation with the gun mechanism in automatic.

The gas ejector begins to function when the gun is in counterrecoil and the breech is opening. At this point, practically at the end of counterrecoil, the trip plate on the slide trips the air valve operating cam. Tripping of the valve cam positions the cam and the valve at valve-open detent position, and ports air through the housing leads and out the orifices in the housing as the falling block uncovers them and as the empty case starts rearward out of the chamber. Air continues to flow up the chamber and bore, until manual movement of the rammer control lever operates the linkage that releases the cam from valve-open position. Spring action then closes the valve and cuts off air flow as the cam moves to valve-closed position.

In single fire, gas ejection can take place as soon as the breech is manually opened, but is cut off by hand.

The 5"/38 breech mechanism just described is, as we've already said, a prototype whose general features appear in several other U. S. naval weapons. We've described the design as it appears in all 5"/38 single mounts and in the right-hand guns of twin mounts. Left-hand guns of twin mounts have identical mechanisms, except that some parts are of opposite hand. The design as it appears in 5"/54 mounts Mk 39 is practically identical.

In 3"/50 mounts Mk 26 and earlier you'll find that the design is similar, with many of the parts even having similar shapes. And in the Mk 27 and later 3"/50 mounts the resemblance persists. But there are modifications because of the electrically-driven mechanical loader which makes the 3"/50 Mk 27 and its successors perform like machine guns even though technically they have semi-automatic breech mechanisms. Let us now examine more closely the breech mechanism used on these new 3"/50 mounts.

BREECH OPERATING MECHANISM (3"/50)

OP 1566 describes the 3"/50 breech mechanism as used in 3"/50 mounts Mk 27 and later as "an automatic vertically sliding block type which is unlocked during gun recoil action and is opened downward by gun counterrecoil energy. Its opening action extracts the empty cartridge case and sets a mechanism that holds the breech open against the load of a breech closing spring. Ramming a fresh round releases these devices to automatically close the breech."

If this description sounds as if it could be applied also to the 5-inch breech mechanisms we have just discussed, the reason is that it could be. If we consider the gun, housing, and breech mechanism without the slide and automatic loader (as shown in fig. 9–12 and 9–13) the points of resemblance in the general layout are easy to see. Even the salvo latch is similar. The hand operating mechanism (not illustrated) is even simpler than the 5"/38's, since it has no bell cranks and functions only to lower the breechblock. But the figures also point up some features which have no counterpart in the 5-inch breech mechanisms we have studied—particularly the breech interlock cam and latch lever; hold-down mechanism, the transfer lever, and push rod; and the shell lock.

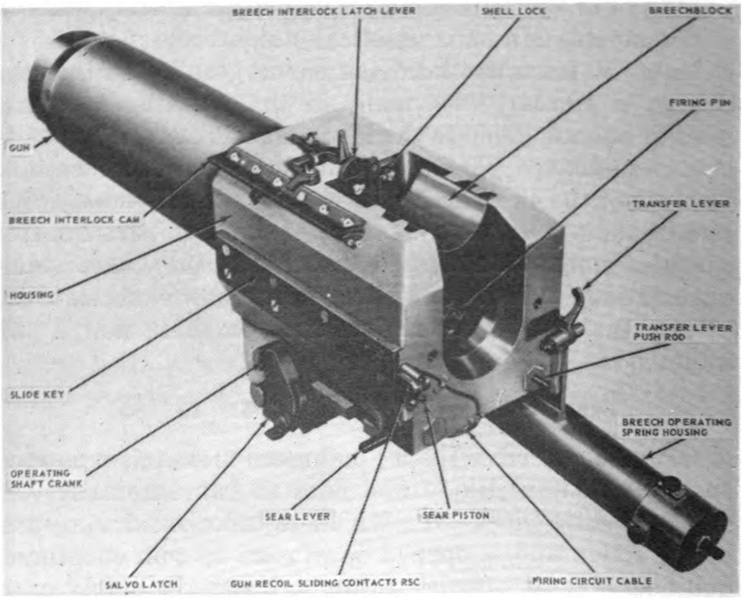


Figure 9–12.—3"/50 gun and housing. General arrangement.

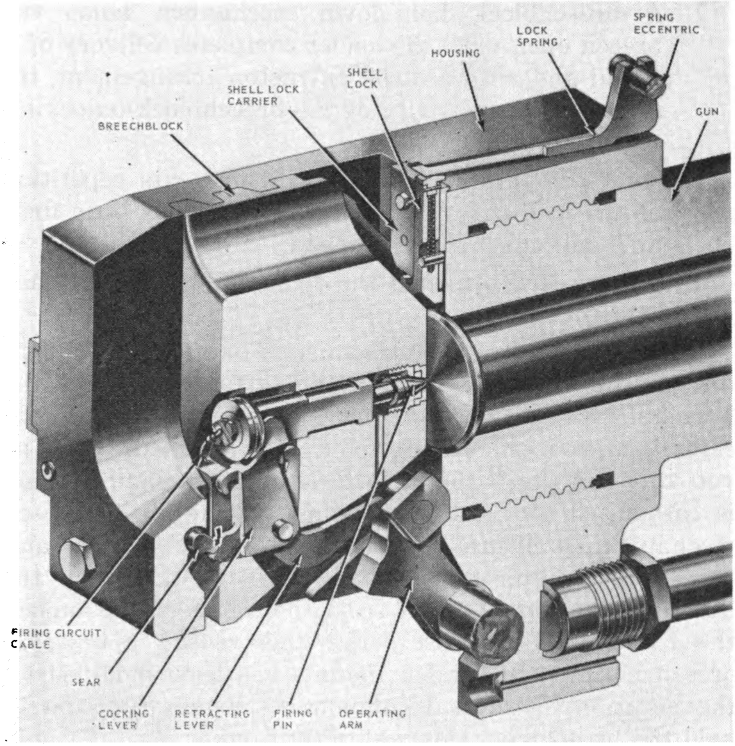


Figure 9–13.—3"/50 breech mechanism. Cut away view.

The breechblock is a vertical sliding-wedge type. It moves as the operating shaft rotates. Much as in the 5"/38 design, in automatic operation the breechblock is lowered and the operating spring is compressed on counterrecoil when the operating-shaft crank is rotated by the operating-shaft cam plate (not illustrated) in the slide. The breech is closed by the operating spring. The positive-type salvo latch on one end of the operating shaft prevents unintentional opening of the loaded breech before the gun has fired. The breechblock houses a firing mechanism. None of this should be new to you. Let's concentrate on the new design features of the breech mechanism, as follows:

1. A breechblock hold-down mechanism holds the breech open until the loader completes delivery of a round and with a novel extractor arrangement, increases the sensitivity of the breechblock-unlocking action.
2. A breech interlock mechanism prevents repetition of the loading cycle until the round has been fired and the breechblock dropped.
3. A shell lock prevents the rebounding of a rammed cartridge.

Earlier 3″/50 breech mechanisms, like the 5″/38 type discussed above, used lugs on the extractors to lock the breechblock down by engaging pallets in the breechblock camming grooves until a round was rammed. But, as you know, in the 3"/50 rapid-fire mount the ammunition is catapulted forward, not rammed. The 3"/50 breech mechanism, as originally designed for hand-rammed ammunition, requires considerable forward thrust on the extractors to unseat them from their pallets and unlock the breechblock to close. For this reason, the 3"/50 breech mechanism for RF mounts has been modified by the addition of several components which function to hold the breechblock down slightly further than it would be if the extractor lugs were in contact with the pallets. The hold-down mechanism is much more sensitive than the pallet-lug mechanism. It unlocks positively when the cartridge case engages the extractors, even though at that instant the cartridge is "coasting" forward instead of being rammed.

The hold-down mechanism is shown in figure 9–14. The hold-down lever is a vertically positioned lever pivoted near its center. When the gun is in battery and the breechblock is in its held-down position, the hold-down lever bears on the hold-down arm of the breech operating shaft, preventing rotation of the shaft and closing of the breech.

The hold-down latch lever secures the hold-down lever

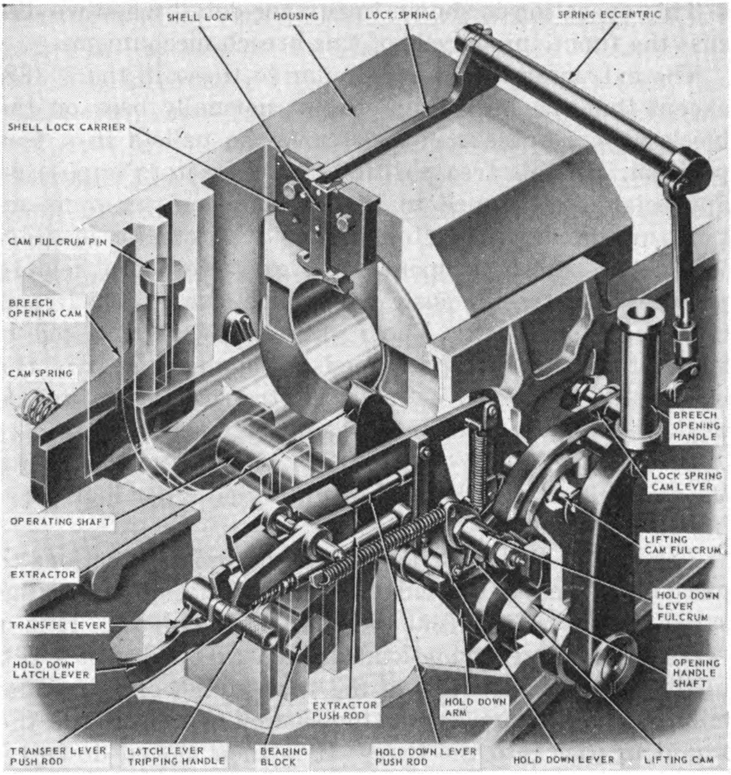


Figure 9–14—3"/50 breech mechanism. General arrangement, breech open.

in place when the latter is holding the block down. The latch lever is disengaged in normal operation by a cam pin on the front right arm of the transfer tray.

The hold-down lever is released from the hold-down arm of the operating shaft in normal automatic loading by movement of the right extractor. When the extractor is carried forward by the rammed ammunition, the extractor push rod is thrust rearward. This actuates the transfer lever, and the thrust is transmitted through another push rod to the hold-down lever, moving it clear of the operating shaft hold-down arm and allowing the block to rise.

This operation is shown in further detail when we discuss the functioning cycle of this breech mechanism.

The extractors are very similar to those in the 5''/38, except that the inner lugs do not normally bear on the block pallets but are poised above the pallets in a free position. In this free position, the extractors impose no appreciable resistance to the ammunition-ramming action, an important factor in rapid automatic loading. While the breech is opened, the extractors are held in position by extractor push rods, which also aid in extracting the empty case. The right extractor push rod is longer than the left and extends through the rear of the breechblock, where it engages the transfer lever for use in the hold-down mechanism as already described.

In case of a failure of the breech hold-down mechanism, the breechblock will be held down by the inner lugs bearing on the pallets.

The breech shell lock (fig. 9–12 and 9–13) functions to prevent a rammed cartridge from rebounding or backing out of the breech to foul the rising breechblock. It is a vertically sliding spring-loaded latch that rides in a slot in the shell-lock carrier on the face of the breech. The latch is moved upward during ramming and allows the round to pass into the bore. It is then moved down by action of the lock spring (mounted on the slide) to trap the seated round. The rising breechblock pushes the shell-lock latch clear. When the gun recoils on firing, the lock spring no longer engages the shell lock, which rises because it is spring-loaded to do so, and remains up until the lock spring forces it down again. Hence it remains clear after firing until the extractors have pulled the rim of the empty case past the shell lock, during extraction.

The lock spring is cammed to allow the shell lock to rise when the breech is opened manually by the hand operating lever.

The breech interlock mechanism, which is technically a part of the loader, is a system of mechanical linkages which functions automatically to stop the loader from delivering another round to the breech whenever there is a round in the bore or the breechblock is up. The breech interlock latch lever (fig. 9–12), the first mechanism in a chain of linkages from the breech face to the loader control lever, is pivoted in the shell-lock carrier next to the shell lock and extends down the breech face, partially in front of the breech opening. When either a round is rammed or the block is raised, the latch lever is moved aside, actuating, through linkages, the loader control lever. This prevents the start of a new loading cycle. The blocking action can be canceled by the hand reset lever. This is necessary after removing a loaded round that has not been fired. There are two designs of breech interlock mechanism—one for the Mk 2 Mod 5 loader, and a different one for Mk 2 Mods 4 and 6 loaders. For further details on them, see OP 1566.

3"/50 Breech Mechanism Functioning Cycle

Now let us watch the 3"/50 breech mechanism as it goes through its automatic functioning cycle. The gun is prepared to fire by unlocking the salvo latch, opening the breech by hand, and stowing the operating handle. (Note: The block must be lowered all the way to the operating shaft stop so that the hold-down mechanism, rather than the extractors, hold the block down. The gun will not function automatically if the extractors rather than the hold-down mechanism are holding the breechlock down.) We assume that the loader is running and is filled with ammunition.

START OF CYCLE. The cycle begins with the breechblock locked down by the hold-down lever (fig. 9–15A). As the ammunition round is catapulted into the breech (fig. 9–15B), it cams the shell lock up. Meanwhile, a pin on the right front arm of the transfer tray of the loader wipes the cam surface at the rear end of the hold-down latch lever (fig. 9–15C). This rotates the latch lever to release the upper end of the hold-down lever. The hold-down

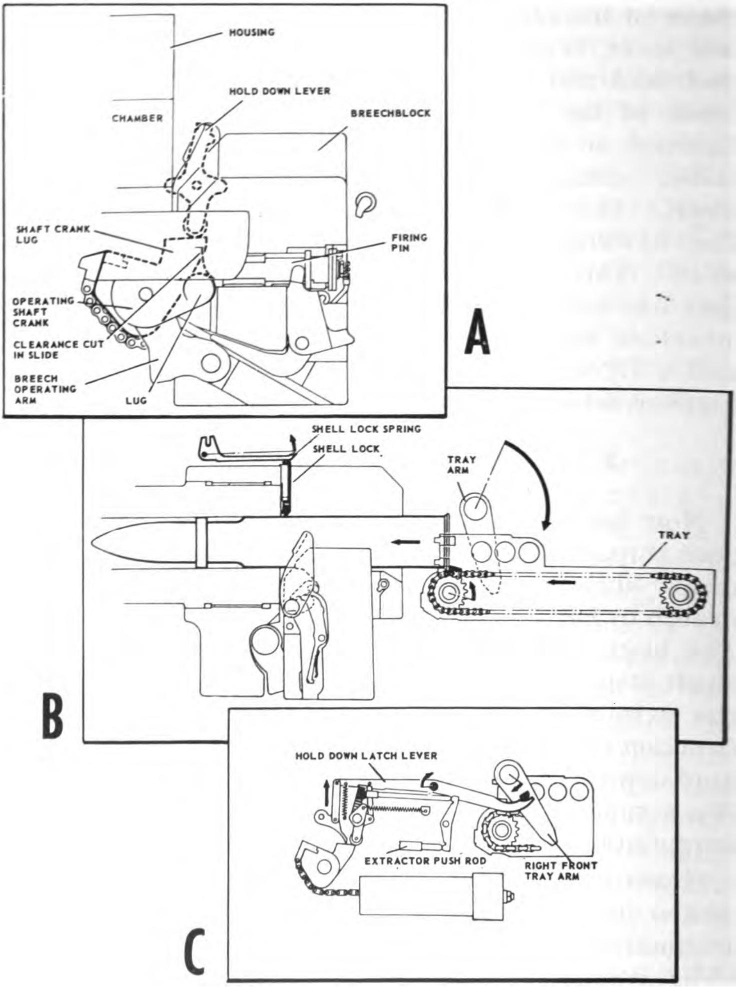
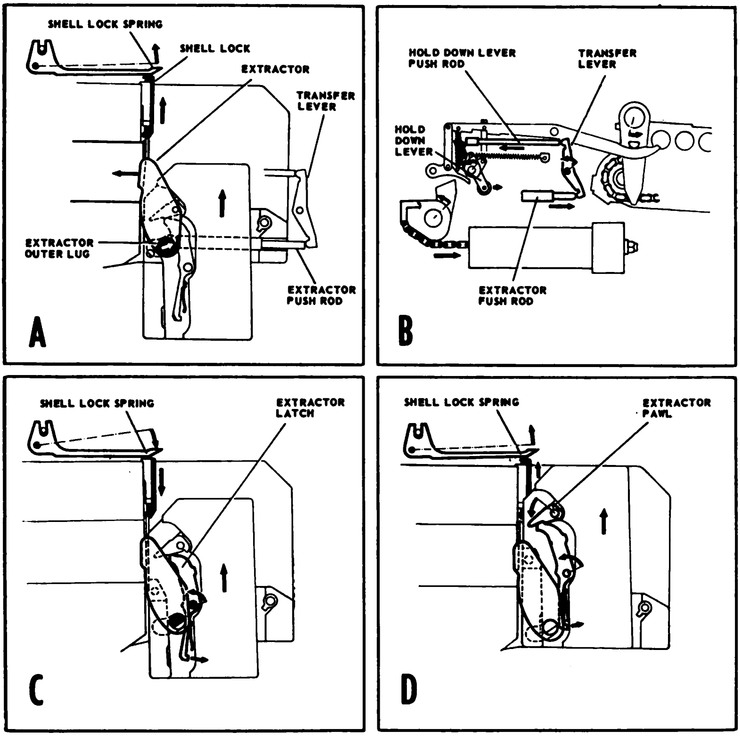


Figure 9–15.—3"/50 breech mechanism functioning cycle. A. Battery position, breech open. B. Catapulting. C. Release of hold-down latch.

lever has not yet released the breechblock, but it is now unlocked so that it can do so.

BREECH UNLOCKING. When the rim of the cartridge case crosses the breechblocks, it engages both extractors and sweeps them forward (fig. 9–16A). This rocks the extractors and thrusts the outer lugs rearward, pushing their plungers.



9–16.—3"/50 breech mechanism functioning cycle. A. Shell lock and extractor actions. B. Hold-down lever release. C, D. Breech closing movements.

At the end of the movement the cartridge case rim cams the shell lock up. When the shell lock comes down again after the rim passes forward (fig. 9–16C), it holds the case in the chamber until the breechblock closes.

In the meantime, the right extractor thrusts its push rod rearward, kicking the transfer lever and hold-down lever push rod to rotate the hold-down lever off the operating shaft hold-down arm. (See fig. 9–16B.) Now the breechblock is unlocked and the operating spring begins to pull it up.

BREECH CLOSING AND LOCKING. In 3"/50 breech mechanisms of this design the extractor inner lugs don't operate in fixed camming grooves in the breechblock. Instead each extractor lug is cammed between a machined surface of the breechblock and a latch pivoted in the block. When the breechblock goes up, the extractor inner lugs force the latch lower ends to the rear (fig. 9–16C) and the upper ends rotate forward until each is engaged by a pawl (fig. 9–16D) that locks it in position.

Meanwhile, the rising breechblock forces the shell lock up (fig. 9–16D) and the breech is fully closed and locked as the salvo latch engages the operating shaft crank. Since this last operation is just like that in the 5"/38 breech mechanism, it isn't illustrated here.

BREECH UNLOCKING AND OPENING. The gun fires, the housing recoils, then counterrecoils. During recoil the salvo latch is cammed to disengage. During counterrecoil a spring-loaded breech opening cam on the slide contacts the operating shaft crank (just as in the 5"/38 mechanism) and the camming action rotates the crank and starts the lowering of the block. (See fig. 9–17A.) When this camming action has the block at its lowermost position, just before the end of counterrecoil, the right operating shaft crank lug is poised just below the hold-down lever (fig. 9–17D).

EXTRACTION. While the breechblock is dropping, the extractors function to haul the fired case out of the chamber and flip it back out of the slide, and the shell lock is cammed to rise. The extractor outer lugs work back and forth in a kidney-shaped slot in the housing, much as in the 5"/38 mechanism. The inner lugs are cammed by the inner surfaces of their respective latches. As the block

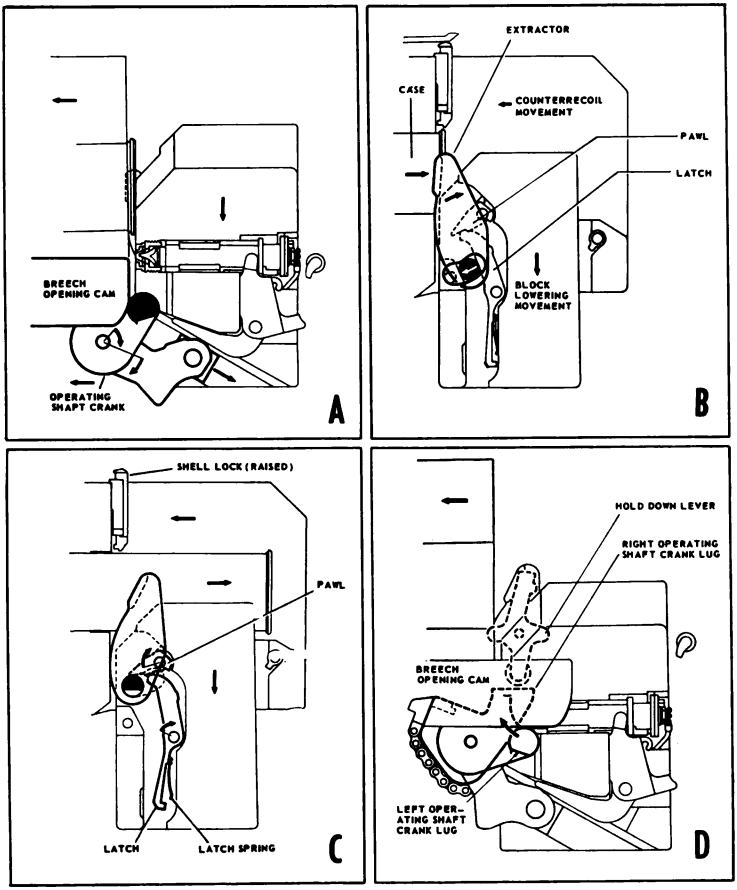


Figure 9–17. 3"/50 breech mechanism. A. Breech being cammed open. B, C. Extractor action. D. Breech open, just before locking.

lowers, the latches move down with it. When the inner lugs are somewhat above the latch pivot, (fig. 9–17B), the latch camming surfaces force them forward. (The latches themselves are held in place by the pawls.) This flips the extractor upper ends to the rear, and snaps the fired case aft. Near the end of counterrecoil movement, when the block is in lowermost position (fig. 9–17C), the inner lugs disengage the pawls from the latches so that the camming action just described doesn't function in reverse as the block rises during the next cycle.

BREECH LOCKING OPEN. When the gun has fully returned to battery, the operating shaft rotates slightly as shown by the arrow (fig. 9–17D), and the breechblock rises slightly until the operating shaft crank lug engages the roller on the hold-down lever, as it was when the cycle started. (See fig. 9–15A.)

Hand Operation of the 3"/50 Breech Mechanism

Because of the additional complications of the loader and breech mechanism that have no counterpart in the 5"/38, hand operation of the 3"/50 breech mechanism is a little different from that of the 5"/38. Let's briefly go over the hand operations you will be concerned with on 3"/50 RF guns.

OPENING THE BREECH. If the gun is not loaded, this is simply a matter of unlocking the salvo latch and pulling the hand operating lever to the rear. (Disengage the salvo latch as you would on the 5"/38.) Camming actions automatically raise the shell lock and unlatch the hold down latch lever. Be sure to pull the hand operating lever all the way down as far as it will go, so as to ensure that the hold-down lever is engaging the operating shaft lug. If you don't haul the breechblock down far enough before you release it, the block may be held down by the extractor inner lugs engaging pallets, instead of by the hold-down lever, and automatic firing will be impossible. And, after the block is locked down, be sure to rotate the hand operating lever forward to its stowed position.

If the chamber is loaded, you must take the proper precautions when opening the breech by hand. If the gun is hot, you must proceed with due regard for the possibility of cookoff. If the round in the chamber has misfired, you must follow regular misfire procedure. Be sure the firing circuit is open. (See chapter 10 on this.) Lower the block slowly, and be sure a man is stationed to catch the extracted round. If the projectile remains seated in the bore, you'll have to ram a short case and fire the projectile out by percussion. If the case fails to extract, use the manual extracting tool on the mount to get it out.

CLOSING THE BREECH. Routine closing of the breech on an empty chamber is done this way:

1. Hold breech hand operating lever in breech-open position.
2. Pull down on hold-down latch lever tripping handle.
3. Trip the extractors by thrusting them forward with a reversed empty cartridge case.
4. Ease up on the hand operating lever, permitting the block to rise slowly.
5. Release lever a couple of inches from stowed position, allowing breech operating spring to snap breechblock to full up position.

In clearing the bore by firing a short case, you close the breech a little differently. First be sure the firing lever on the loader is set at ELECTRIC. Then trip the hold-down lever so that the breechblock is held down by the extractors seated on the pallets. To ram, use the rubber-tipped hand ramming tool ONLY. Insert the tool through the loader from either lower corner of the loader side plate, and push the short case forward with a sharp thrust. When the extractors are pushed forward, the block will rise, knocking the ramming tool out of the way.

CAUTION: Do NOT try to ram with the tool held horizontal—as it would be when inserted from the midsection of the rear of the loader. When the breech closes, it will then most likely mash the tool instead of merely knocking it out of the way.

OP 1566 describes a procedure in which one man eases the block up with the hand operating lever while the other rams. This procedure is satisfactory, but requires two men working together, while the suggested procedure above can be performed by one man working alone.

For more details on firing by percussion, see chapter 10.

PRECAUTIONS IN BREECH HAND OPERATION:

1. Remember to open the firing circuit and lock the slide to prevent movement in elevation. Do this whenever you're working around the loader or breech mechanism.
2. Shut off the loader drive motor whenever you have to put tools or your hands or arms through the loader while working around it.
3. Never try to raise the breechblock with a mallet if it sticks. See OP 1566 on the recommended procedure.

That concludes our discussion of the 3"/50 breech mechanism. In studying it, remember that through electrical interlocks and mechanical actions these functions are coordinated at the beginning and end of the cycle with loader operations, which are described in chapter 8. Naturally, we have omitted some details, since we've concentrated on the main aspects of the mechanisms and its functioning, and since we haven't space here to go into minor differences between different mods of the equipment. See OP 1566 for most of this information.

5"/54 BREECHBLOCK OPERATING SYSTEM FOR MK 42 MOUNTS

This mechanism is the highest development so far of gun breech mechanisms in this caliber that you are likely to see now or in the near future in the U. S. Fleet. The equipment is (as noted in the introductory discussion of the mount as a whole in the preceding chapter) still classified; all we can give you here is a brief overview of it with not much detail. If you're assigned to a ship that has this equipment aboard, look up the reference on it in OP 0.

In this gun assembly the breechblock, extractor mechanism, and firing mechanism are essentially one large interlocked system that is mechanically and hydraulically operated and controlled as a unit. The basic component of the system is the breechblock, and the operation of the extractor and firing mechanisms is actually a function of

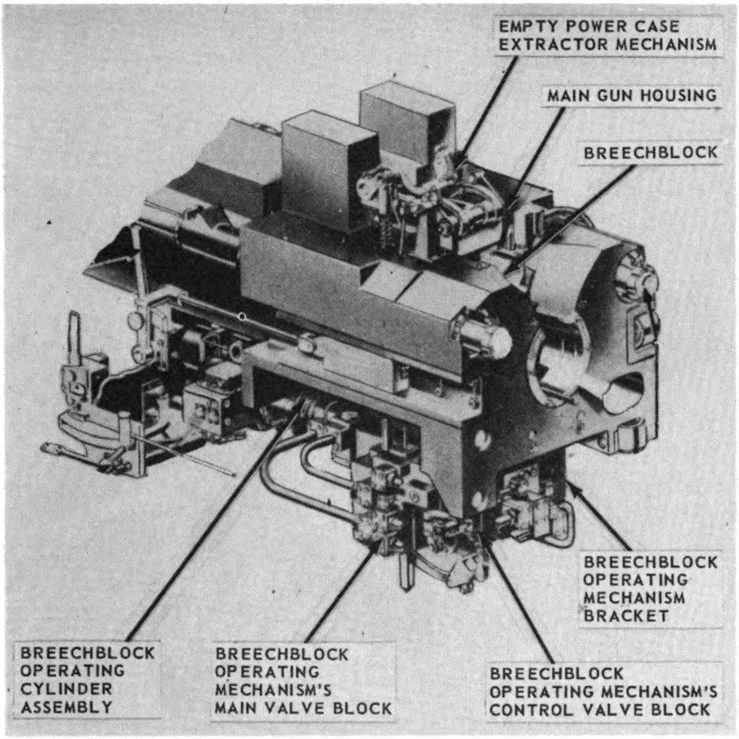

EMPTY POWER CASE EXTRACTOR MECHANISM
MAIN GUN HOUSING
BREECHBLOCK
BREECHBLOCK OPERATING MECHANISM BRACKET
BREECHBLOCK OPERATING CYLINDER ASSEMBLY
BREECHBLOCK OPERATING MECHANISM'S MAIN VALVE BLOCK
BREECHBLOCK OPERATING MECHANISM'S CONTROL VALVE BLOCK

Figure 9–18.—5"/54 breechblock operating system assembly. Left side view.

the breechblock operating system. Hence its nomenclature; it is a BREECHBLOCK OPERATING SYSTEM, not merely a breech mechanism.

Figure 9–18 illustrates the system as a whole, while figure 9–19 shows in detail the breechblock and some of the surrounding mechanism (though the hydraulic breech operating cylinder and some other components are here omitted). The breech operating mechanism hydraulic components are mounted below the housing, with their mechanical linkages to the breechblock working through a bracket at the rear of the housing.

The breechblock itself is a vertically moving steel block that operates in guides that shift the block slightly for-

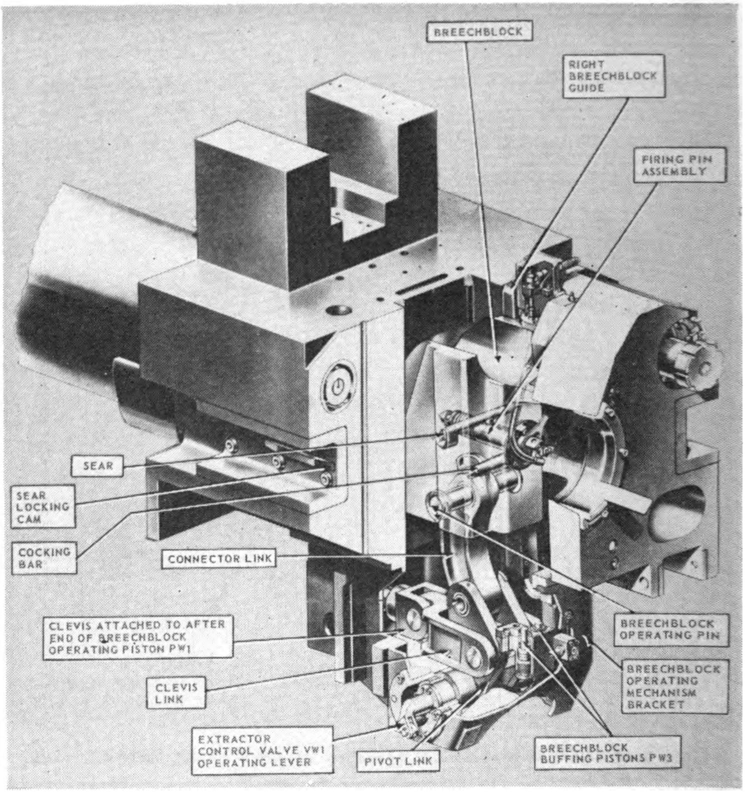

BREECHBLOCK
RIGHT BREECHBLOCK GUIDE
FIRING PIN ASSEMBLY
SEAR
SEAR LOCKING CAM
COCKING BAR
CONNECTOR LINK
CLEVIS ATTACHED TO AFTER END OF BREECHBLOCK OPERATING PISTON PW1
CLEVIS LINK
EXTRACTOR CONTROL VALVE VW1 OPERATING LEVER
PIVOT LINK
BREECHBLOCK BUFFING PISTONS PW3
BREECHBLOCK OPERATING MECHANISM BRACKET
BREECHBLOCK OPERATING PIN

Figure 9–19.—5"/54 mount Mk 42. Breechblock operating mechanism. (Cutaway view.)

ward as it rises to closed position, to give the wedging effect you are already familiar with. The block is driven by a piston in the breechblock operating cylinder under the housing through a linkage that pivots on the breechblock operating meçhanism bracket. Most of the linkage details are visible in figure 9–19.

The extractor is a two-armed piece straddling the breech opening. It is mounted on the top of the breech housing and is operated by an independent hydraulic cylinder controlled by the same valve block that controls the breech operating cylinder. In figure 9–18 only the top of this assembly is visible; in figure 9–19 it has been omitted in order to show the other breech mechanism parts.

Now, without attempting to go into details on the hydraulic units of the equipment, let's go over the main outlines of the breechblock system functioning cycle.

We begin with the system ready to begin its cycle. The breechblock is down, the extractor arm is retracted (the ends of its two blades or fingers nest into recesses in the breech face like those of 5"/38 breech mechanisms), and the gun is unloaded and in battery. (Note: The loader mechanism and the rammer are not illustrated in this chapter.)

RAMMING. The rammer, which mechanically somewhat resembles the twin 5"/38 rammer with its two racks and a pinion to which the rammer spade is attached, thrusts the cartridge case into the chamber. The spade latches in fully forward position until the breechblock has finished rising.

BREECH CLOSING. The rammer yoke cams a linkage that ports high-pressure hydraulic fluid into the forward end of the breechblock operating cylinder, and the piston moves to the rear, raising the block. As breechblock closing is completed, the rammer spade is pushed up out of the way, and interlock devices are actuated to synchronize loader operation with breech operation.

BREECH OPENING AND EXTRACTION. If the mechanisms have functioned properly and the necessary interlocks have functioned, the firing circuit can be completed and the gun fires. As the housing moves aft in recoil, a roller linked to a breechblock operating cylinder control valve follows a camming surface on the slide and the control valve ports high-pressure hydraulic fluid to the after end of the breech operating cylinder. This drives the piston forward and lowers the breechblock, which is buffed to a stop in completely lowered position.

In the last fraction of an inch of its downward movement, the breechblock operates the extractor control valve to port high-pressure hydraulic fluid into the top of the extractor operating cylinder, driving the piston down. This retracts the extractors, and the fired case is kicked out.

SYSTEM RECOVERY. Next, the extractor operating piston is returned by a spring in the extractor operating cylinder to its previous position, and this retracts the extractor itself to stowed position. All valves and interlock devices in the system are restored to the position they had before the cycle began, and the gun is now ready for reloading.

BREECH MECHANISM MAINTENANCE POINTERS

The breech mechanisms we've discussed in this chapter have a good deal in common, in spite of differences in design, so far as maintenance is concerned. In this section we take up a number of pointers that you should keep in mind when you are doing maintenance work on these mechanisms. By the way, be sure you check also the section in the next chapter that similarly takes up maintenance of firing systems.

The common breech maintenance work that you'll be called on to do can be divided into several phases, which are discussed separately below.

INSPECTION AND EXERCISE. Every breech mechanism must be inspected daily, whether or not it has beeen fired, as well as before and after firing. This includes opening and closing the breech by hand, and looking it over carefully in both positions. Look for cracks, bent or deformed parts, signs of galling or scoring, corrosion, and unusual looseness or tightness of operating parts. Make sure the breech opens and closes completely. (Check the breech-closed index.)

With breech mechanisms incorporating hydraulic components, exercising involves energizing the hydraulic system and putting the mechanism through its paces under power. With mechanical breech mechanisms like the 3"/50 and 5"/38, you use the breech operating handle and the tool supplied with the mount for tripping the extractor.

When firing is not being done, it's also advisable to take the opportunity afforded by running the gun in to let the breech mechanism function as it would normally. This is also a good time to check the functioning of the salvo latch.

Remember to check the gas ejector of the gun, if it has one, in the course of exercising it.

LUBRICATION. Keeping the breech mechanism lubricated means not only applying the proper lubricant, but also removing excess of old lubricant when necessary. Follow the OP closely on this, particularly with respect to changing lubricant when in Arctic or Antarctic climates. Remember that all brightwork surfaces, even if no specific lubricant is called out in the OP, should be protected by a light film of oil. And, in lubricating, be sure to keep electrical parts of the firing mechanism free of lubricant.

ADJUSTMENTS AND REPAIRS. One reason for failure of the breechblock to close completely may be insufficient tension of the operating spring. Follow the OP's instructions in regulating this, and be SURE to check the adjustment by cycling the mechanism, using a dummy cartridge case.

But note that you'll get stiffness and sluggishness in breech mechanism action for other reasons too. Foreign matter, especially if it's caught in the breechway, can make it difficult for the breechblock to move either up or down. Use your rawhide maul to get the breechblock moving when you have to in the heat of action, but remember that it's no substitute for taking down the mechanism and eliminating the CAUSE at the first opportunity.

Other possible causes of breech mechanism malfunction may be galling of the breechblock ways, operating shaft surfaces, bearing blocks or their ways, or the breech opening cam. To inspect for such galling, remove lubricant and feel with the fingers.

Seriously galled parts must be replaced. Slightly scored surfaces can be restored to good functioning condition by stoning. If burs are found, remove by stoning. Clean all particles from the mechanism before stowing. Never use emery dust or like substances to condition any parts of the breech mechanism.

Here are two wise precautions:

1. Always inspect the breech for galling and for burs after EVERY firing operation.
2. Always remove breechblock lubricant before servicing any breech parts. Use kerosene or other approved petroleum solvent.

SUMMARY

In this chapter you have studied the naval gun breech mechanisms (other than those of small arms and machine guns) with which you will be primarily concerned as a GM2. We have not taken up firing mechanisms and systems; for these, see the next chapter.

QUIZ

In each of the following questions, select the ONE BEST answer.

1. In automatic operation, the 5"/38 breechblock is lowered
   a. when the extractors engage the pallets
   b. when the salvo latch is unlocked
   c. when the housing is counterrecoiling
   d. when the operating shaft cam plate is retracted

2. When the 5"/38 breechblock is down, the extractor inner lugs engage
   a. the cartridge case rim
   b. the kidney-shaped slots in the housing
   c. the pallets in the breechblock camming grooves
   d. none of the above

3. The 5"/38 breech mechanism operating spring tends to turn the operating shaft so as to
   a. close the breech
   b. open the breech
   c. lock the breechblock in breech-closed position
   d. keep the breech mechanism unlocked when the block is down.

4. After you open a 5"/38 breech mechanism by hand, you must always
   a. lock the breech open by setting the extractors
   b. engage the sliding latch in the hand operating crank
   c. set the operating shaft cam plate to "S".
   d. push the hand lever forward until it latches in stowed position.

5. In normal firing, the 5"/38 salvo latch engages the operating shaft crank when
   a. the hand operating lever is retracted
   b. the operating shaft crank is cammed by the cam plate
   c. the salvo latch lug is cammed by a cam plate in the slide
   d. the breechblock rises to close

6. In normal firing, the 5"/38 or 5"/54 gas ejector cuts off the air blast into the chamber when
   a. the rammer control lever is depressed
   b. the breechblock rises to fully closed position
   c. a trip plate on the slide trips the air valve operating cam.
   d. the freshly rammed cartridge case blocks the gas ejector ports

7. Which of the following statements is true only of the 5"/38 and not of the 3"/50 breech mechanism?
   a. The extractors rock rearward when the breechblock lowers.

   b. Forward movement of the extractor upper ends frees the breech mechanism to close.
   c. The extractors engage part of the breechblock to hold the breech open.
   d. The breech mechanism operating shaft is turned by camming action in counterrecoil.

8. In the 3″/50 breech mechanism, the camming action of the right front tray arm pin of the loader causes the hold-down latch lever to
   a. unlock the hold-down lever
   b. transmit extractor movement to the push rods
   c. release the breech operating shaft
   d. disengage the operating shaft hold-down arm from the hold-down lever
9. During counterrecoil, the latches in the 3″/50 breechblock are
   a. locked by the extractor outer lugs
   b. unlocked by the extractor inner lugs
   c. unlocked by the extractor outer lugs
   d. locked by the extractor inner lugs
10. During extraction, the shell lock is raised to permit passage of the rim of the fired case because
    a. the rim cams the shell lock upward
    b. the lock spring is cammed to rise, allowing the spring-loaded shell lock to move upward
    c. the lock spring is cammed to rise, and pulls the shell lock up with it
    d. the lock spring does not contact the spring-loaded shell lock, and the lock therefore rises
11. In the 5″/54 gun mount Mk 42, breech-closing action is initiated when
    a. the extractors are carried forward by the rammed cartridge case and unlock the block
    b. the extractors are carried forward by the rammed cartridge case and operate a valve that ports fluid to the breech operating cylinder
    c. the rammer yoke cams a linkage to operate the breech operating cylinder
    d. the rammed cartridge case cams an interlock to operate a valve that ports fluid to the breech operating cylinder

CHAPTER 10

FIRING SYSTEMS

INTRODUCTION

In the preceding chapter we studied the breech mechanisms of several typical naval weapons. We went into some detail on their components and their functioning. However, in concentrating on breech mechanisms and operations, we omitted the firing mechanisms which they house. In this chapter we complete our study of breech mechanisms by taking up firing mechanisms, as well as other components that have to do with the firing function.

BRIEF REVIEW OF GUN FIRING

As you remember from the preceding course in this series, firing mechanisms function to initiate the burning of the propelling charge by setting off a primer. (You may want to review briefly the construction and functioning of gun ammunition propelling charges; see chapter 2 of this course.) This they do in either of two ways—by percussion or impact, or by quick heating through use of an electric current. Primers may be designed for either method of initiation, or for both. Present-day 5-inch ammunition is equipped with combination primers. Ammunition for 3"/50 RF guns is electric-primed.

The firing mechanisms we shall study in this chapter are also combination types, designed for firing the primer either electrically or by mechanical impact. The normal firing method is to use an electric current from a low-voltage (around 20 to 24 v) transformer. For local firing in case of power failure or other emergency a 6-v battery can be used. When because of electrical failure or for other reasons the electrical firing method cannot be used or doesn't work, the round is fired by percussion. In 5-inch mounts other than the Mk 42, this means simply that the pointer uses his firing treadle instead of the firing key; through a linkage, the cocked firing mechanism in the breechblock is released to transmit an impact to the combination primer. (In the Mk 42, the firing mechanism in the breechblock functions in much the same way, but it is released by operating a special control handle instead of a foot treadle.) In 3"/50 rapid-fire mounts the firing mechanism in the breechblock cocks and releases mechanically for percussion firing, but it cannot be used on the electric-primed service ammunition. It is used only on short cases, as will be described later.

5"/38 FIRING SYSTEM

Now let's look in further detail at the 5"/38 firing system, which, like the 5"/38 breech mechanism, can be treated as typical. Just about everything that's said in this chapter about the 5"/38's firing system can also be said of the 5"/54 Mk 39, though not always of the 5"/54 Mk 42 or of the 3"/50.

We can consider the 5"/38 firing system as consisting of the following:

1. Electrical system.
2. Firing mechanism proper (in the breechblock).
3. Percussion firing linkage.
4. Firing stop mechanism.

Electrical Firing Circuit (5"/38)

Figure 10–1 shows in schematic form the electrical firing system for a typical 5"/38 mount. Normally the system works on a-c from the ship's 115-v supply. The remote firing key identified in the figure may be a key operated by a crewman in the director, or a key in plot, or an automatic switch in the stable element in plot. Figure 10–1 is a simplified schematic that doesn't show all details.

In any case, the remote firing key or switch is in the primary circuit of the firing transformer in the gun mount. In the secondary (20-v) circuit are a two-position selector commonly called a firing snap switch, the pointer's key, the firing stop switch, and the firing mechanisms in the breechblock. As you can see, the circuit is completed through the cartridge primer, which is grounded through the cartridge case and gun mount structure.

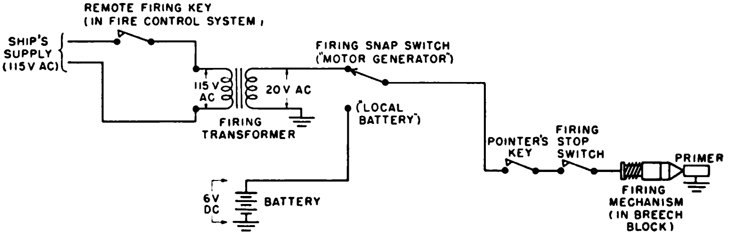


Figure 10–1.—5"/38 electrical firing system. Simplified schematic.

Naturally, since all switches in the secondary circuit are in series, all must be closed before the firing pin can feed current into the primer. That is why the pointer holds his key closed when the mount is firing by remote control.

The firing snap switch can be set in either of two positions. In the MOTOR GENERATOR position, so called even though in most mounts the firing current comes from the firing transformer rather than from a motor-generator, the gun can be fired either by remote control or in local. In LOCAL BATTERY or BATTERY position the firing current is produced by a 6-v battery.

The firing stop switch, like the pointer's key, is always in the circuit and will prevent firing if it is not closed. Later in this chapter we'll describe in further detail the firing stop mechanism of which this switch is a part.

The firing stop switch is an electrical interlock that prevents firing when the gun is not in a safe position. In 3"/50 RF mounts, in the more complicated electrohydraulically operated gun mechanisms like the 5"/54 Mk 42, and in the new 6-inch and 8-inch rapid-fire turrets, this principle of electrical interlocking to permit firing only under certain circumstances is elaborately applied. There will be more about this later in this chapter.

Now let's go on to look more closely at the firing mechanism in the breechblock.

Firing Mechanism and Breechblock Parts (5"/38)

Often you'll see the term "firing mechanism" applied to the whole combination of electrical and mechanical elements that in this chapter we've been calling a "firing system." But, strictly speaking, the term "firing mechanism" should be applied only to the independent assembly in the breechblock that comprises the firing pin and the other subassemblies and parts associated with it. Sometimes this mechanism is called the "firing lock." Again, strictly speaking, a "firing lock" is an assembly used for firing bag guns. It is similar in purpose but different in function and construction from the firing mechanism found in the breechblock of a 5"/38 gun assembly, or in the breechblock of any other sliding wedge breech gun.

The 5"/38 firing mechanism is a cylindrical assembly with the FIRING PIN protruding at one end and the COCKING HANDLE and FIRING TERMINAL at the other. Figure 10–2 shows two views—an exterior and a cutaway. The firing pin and terminal are electrically insulated from the other parts by two fiber INSULATING WASHERS (only one is labeled in fig. 10–2) and the fiber FIRING PIN SLEEVE.

When the firing mechanism is mounted in its place, only the cylindrical MECHANISM LOCK is firmly locked to the mounting. The other parts can slide back and forth, as follows:

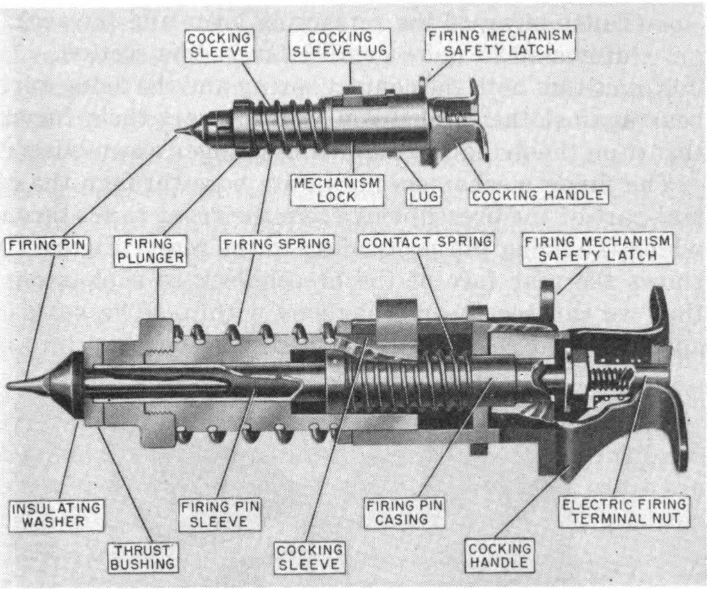


Figure 10–2.—Firing mechanism (5"/38). Exterior and cutaway.

1. The firing pin with its casing, sleeve, washers, firing terminal, and cocking handle, can move as a unit, and are under the continuous forward thrust of the CONTACT SPRING.
2. The FIRING PLUNGER, COCKING SLEEVE, and COCKING SLEEVE LUG can move as a unit, and are under the powerful thrust of the FIRING SPRING. When the firing spring is fully compressed, the firing mechanism is COCKED. It can be cocked by hand, when mounted or when clamped in a vise, by pulling back firmly on the cocking handle. To lock it in the cocked position, twist the firing mechanism safety latch downward. You must cock and lock the firing mechanism in this way when removing it or installing it in the breechblock. In normal operation, in the breechblock, the firing mechanism is cocked and locked in a different way by the automatic

functioning of the retracting lever and the sear, as discussed in more detail later in this section.

Notice that both the contact spring and the firing spring bear against the mechanism lock to exert their forward thrust on the firing pin and firing plunger assemblies.

The firing mechanism fits into a bore through the central part of the breechblock from the front face (through which the firing pin protrudes) to the rear. Figure 10–3 shows the rear face of the breechblock as a phantom so that we can see the mechanisms within. The SEAR is a spring-loaded rod in a transverse hole opening into one

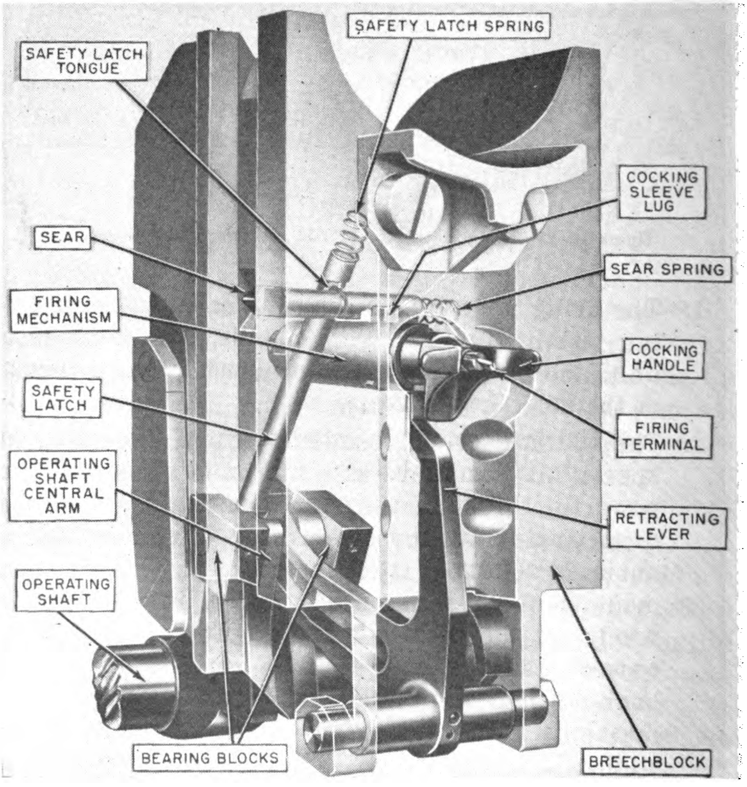


Figure 10–3.—5"/38 firing mechanism and associated components in breechblock.

of the grooves in the left side of the breechblock. It normally engages the cocking sleeve lug. The sear is cut away, however, so that when it is pushed in (to the right, against its spring), the lug is free to move forward.

Also engaging the sear is the SEAR SAFETY LATCH, another spring-loaded rod in a diagonal hole drilled in the breechblock. When the breechblock is closed, the lower end of the latch rides on the operating shaft central arm of the breech mechanism.

Where the latch crosses the sear, it is partly cut away, and a ridge (the SAFETY LATCH TONGUE) in the cutaway portion can engage an annular groove that rings the sear. When the breechblock is open, the tongue rides in the annular groove, locking the sear. When the breechblock closes, the operating shaft central arm cams the safety latch up so that the tongue is disengaged, and the sear can move to the right.

Now let's look into the breech mechanism's functioning in electrical and percussion fire, describing the other mechanisms involved as we go along.

ELECTRICAL FIRE. In electrical fire, the firing mechanism's function is to make good electrical contact with the primer base when the breech is closed. The elaborate system including the firing spring, firing plunger, sear, safety latch, and so on, described a few paragraphs earlier, plays no part in electric firing. In the firing mechanism the parts essential to electrical fire are the firing pin proper, the contact spring, and the firing terminal (fig. 10–4A).

The firing cable is connected to the terminal and moves up and down with the breechblock. The firing current travels through the firing terminal and pin. The contact spring holds the point of the firing pin firmly against the primer in order to ensure good electrical contact. To do this, the tip of the firing pin must protrude from the face of the breechblock. (See fig. 10–4A.)

However, when the breechblock is in any other than

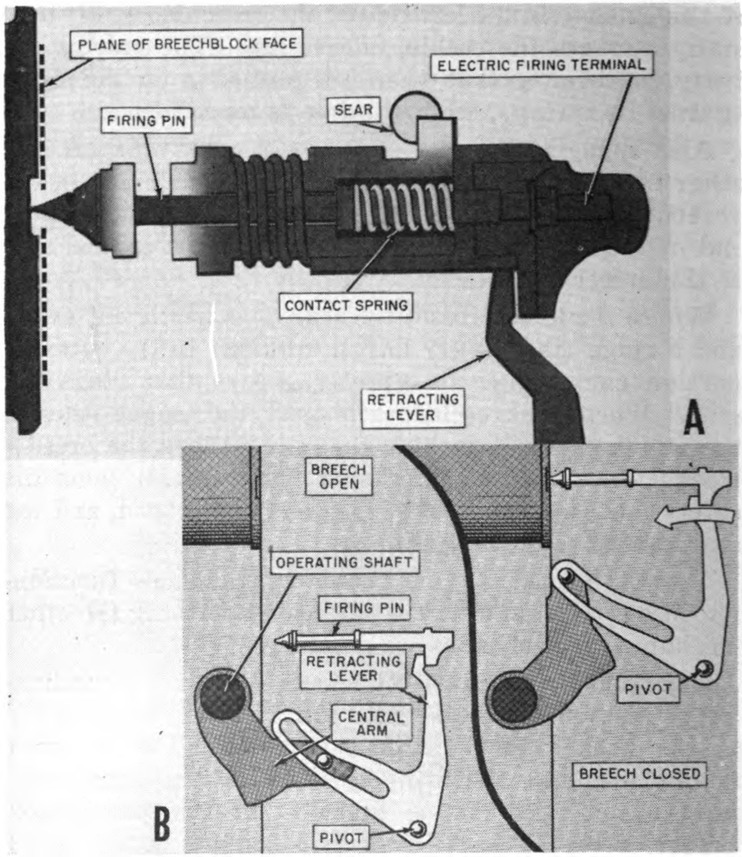


Figure 10–4.—Functioning of 5"/38 firing mechanism in electrical fire. A. Firing mechanism parts. B. Retracting lever.

completely closed position, a protruding firing pin tip is a hazard—it can short the firing circuit, foul a cartridge case, or be bent out of alignment and jam. Hence the firing pin tip must be retracted whenever the breechblock is not fully closed. The component that does this is the RETRACTING LEVER (fig. 10–4B).

The retracting lever rocks on a pivot in the breechblock. It is linked to the central arm so that when the breech is open, its business end pushes the firing pin backward; when the breechblock rises to closed position, the lever rocks the other way so that the contact spring can push it forward again (fig. 10–4B).

When the breech is open the retracting lever also cocks the firing spring. Remember this for the discussion on percussion firing which follows.

PERCUSSION FIRE. In percussion firing, the primer's shock-sensitive bottom must receive a substantial mechanical impact. As you remember, this is done in small-arms weapons and machine guns by using a firing pin. When the firing control or trigger is operated, the firing pin is driven forward by a strong spring, by camming action, or by the inertia of the forward-moving bolt, and the shot is fired when the pin collides with the primer.

In the 5"/38 firing mechanism the firing pin maintains a firm contact with the primer so long as the breechblock is closed on it. The firing pin is not retracted and driven forward as in machine-gun mechanisms; it remains in contact with the primer. The impact necessary to set off the primer is developed elsewhere in the firing mechanism; the firing pin merely TRANSMITS the blow much as a drift or nail set transmits the blow of a hammer.

Percussion Firing System (5"/38)

To see just how this is done, let us now trace the operation of the percussion firing system on a 5"/38 mount, starting with the foot-firing treadle operated by the pointer, and continuing through its linkage to the firing mechanism in the breechblock.

Structurally, the linkage from the firing treadle to the slide is part of the carriage. The arrows in figure 10–5 show how each part of the linkage moves when the pointer steps on the treadle. The treadle tilts down, swinging the rectangular connection lever assembly aft, and so rotating the firing rod. (The encircled area in the figure encloses a clutch connection which is part of the firing stop mechanism to be discussed later.) A little firing rod lever at

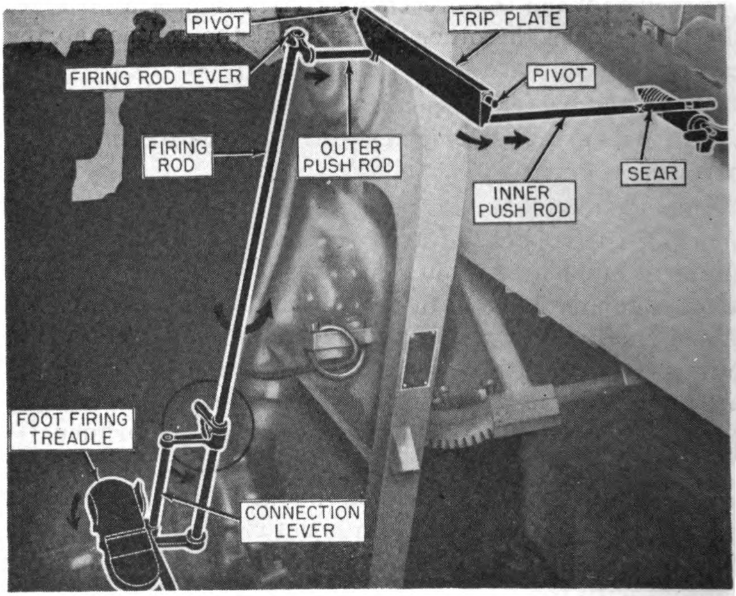


Figure 10–5.—5"/38 firing system. Percussion firing linkage.

the top of the firing rod pushes the outer push rod, which runs inboard through the center of the trunnion.

In turn the rod rotates the trip plate mounted on the inner surface of the slide, and the trip plate transmits the push to the inner push rod in the housing. The inner push rod accomplishes the entire purpose of this linkage, which is to push the sear to the right.

You can depress the foot-firing treadle at any time, but note two important safety features of this linkage:

1. The trip plate can push the inner push rod only when the gun is completely in battery.
2. The inner push rod can push the sear only when the breechblock is fully closed.

In short, the whole linkage described does but one thing—it pushes the sear to the right. The sear, in turn, releases the mechanism which causes the firing pin to set

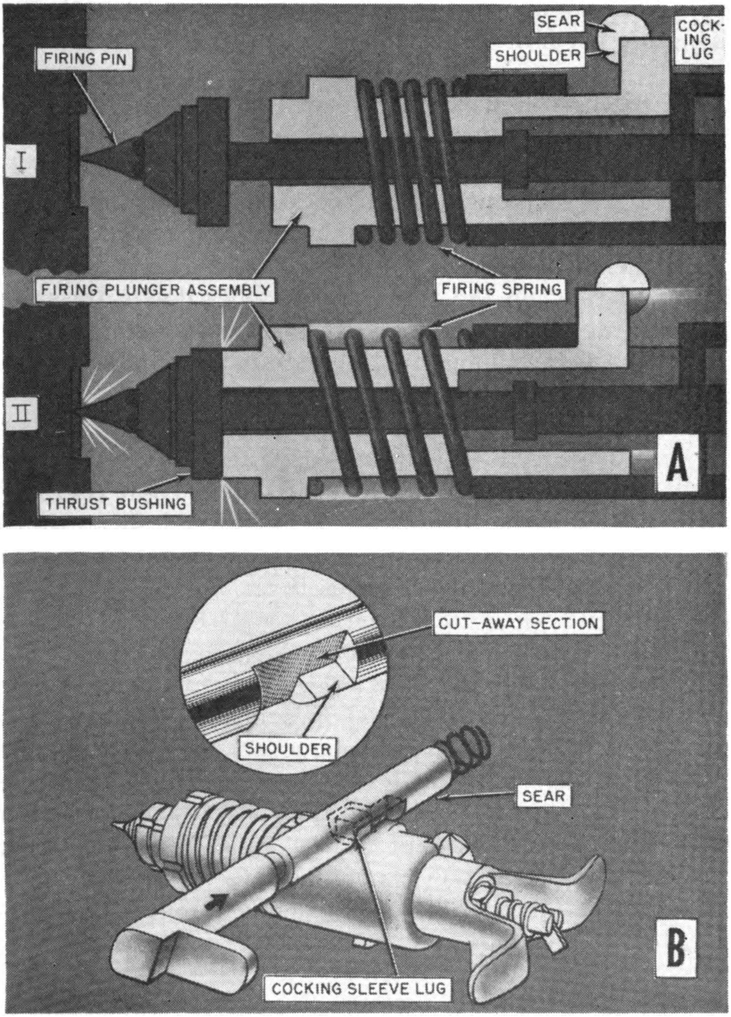


Figure 10–6.—5″/38 firing system. A. Firing mechanism functioning. B. Sear functioning.

off the cartridge primer. Let's now look more closely at how this is done.

As we saw above, the retracting lever pulls back the firing pin when the breech opens, compressing the contact spring. We saw also that it compresses the firing spring. When the breech closes, the retracting lever permits the firing pin to move forward again under the thrust of the contact spring. But the firing spring remains compressed, because the sear engages the cocking lug, and does not let the firing plunger assembly move forward. (See position I, fig. 10–6A).

However, when the firing treadle goes down, the sear releases the cocking lug, and the powerful firing spring drives the firing plunger solidly against the thrust bushing and the firing pin (position II, fig. 10–6A).

To see how the sear controls movement of the cocking lug, study figure 10–6. The lug bears against the shoulder of the sear. When the sear is pushed to the right (arrow) by the firing linkage, the lug can pass through its cutaway section. When the firing mechanism is cocked again, the sear spring pushes the sear back to the left.

Figure 10–7 shows what the safety latch does. It functions to prevent sear movement when the breech is not fully closed. When the breechblock is even slightly below breech-closed position, the latch is pushed down by the spring (arrow 1) until its tongue engages the annular groove in the sear, thus locking it. Only when the breechblock is fully closed and the central arm has risen to the top of its movement (arrow 2) is the safety latch pushed upward (arrow 3) by a flat spot on the operating shaft ceneral arm. This disengages the tongue, permitting the sear to move when the foot-firing treadle is depressed.

3"/50 FIRING SYSTEM

Rapid-fire 3"/50 mounts fire service ammunition fitted with electric primers only. However, the firing mechanism (that is, the assembly in the breechblock) used in

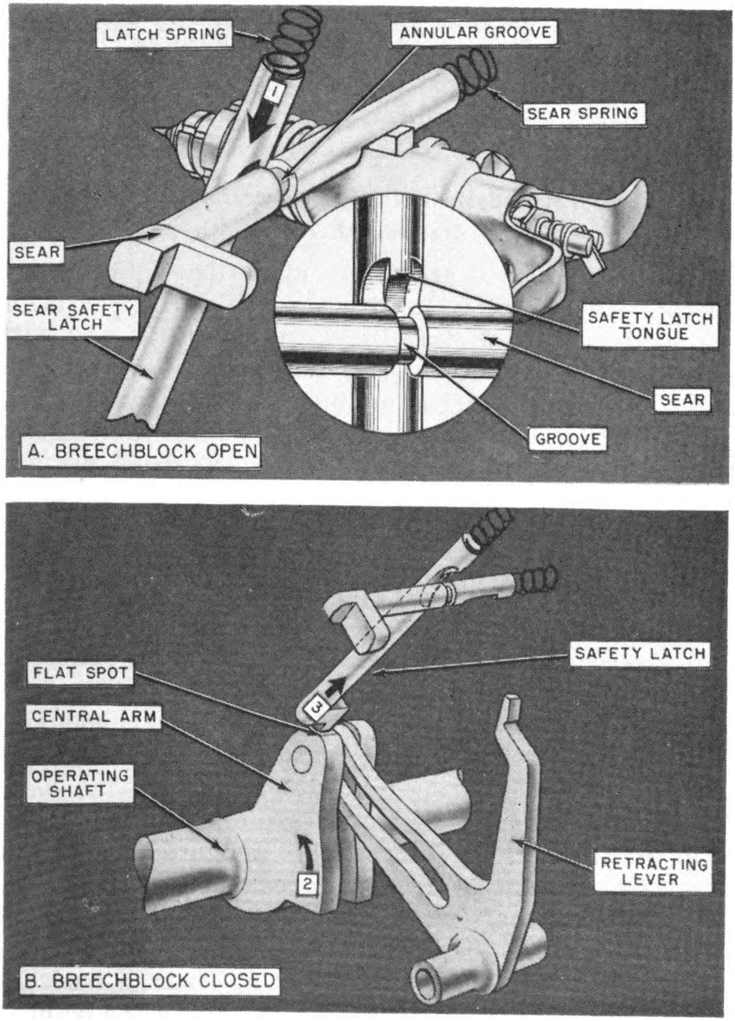


Figure 10–7.—5"/38 firing system. Functioning of safety latch.

these mounts bears a strong family resemblance to the 5"/38 mechanism we've just studied. Percussion fire is rare, and is strictly an emergency procedure; hence the provisions for using it are less elaborate in design and rather less handy to use than they are in the 5"/38. First we'll look at the 3"/50 firing mechanism's mechanical parts, then the electrical components, and finally we'll go into its functioning for both electrical and percussion fire.

3"/50 Firing System: Firing Mechanism and Other Breechblock Parts

Figure 10–8 is a cross section of the 3"/50 breech mechanism in breech-closed position, showing the firing mechanism parts in place in the breechblock. As with the 5"/38 firing mechanism, the mechanism lock, the after part of the firing mechanism assembly, locks in place when it is inserted and rotated until its two ears engage recesses in the breechblock. The firing pin is a steel rod with a conical nose which, under the thrust of the contact spring, bears against the primer of the cartridge in the chamber. It is insulated by plastic sleeving and washers from the remainder of the firing mechanism. At its after end is the cable terminal (either a nut and screw arrangement or a cable slip coupling). The forward end of the percussion firing spring thrusts against the cocking sleeve. The cocking sleeve, a hollow cylinder that encloses the percussion firing spring, serves as the "hammer" in percussion firing.

Again as in the 5"/38, the firing pin is retracted whenever the breech is not fully closed. In figure 10–8 you can see the retracting lever, which is cammed by the arm of the operating shaft when the operating shaft begins to turn, but before the breechblock begins to drop. The camming action causes the retracting lever to push the firing pin sleeve to the rear, thus retracting the point of the firing pin. But from here on the action is different from the 5"/38. The firing pin sleeve is independent of the cocking sleeve, and this retracting action does NOT

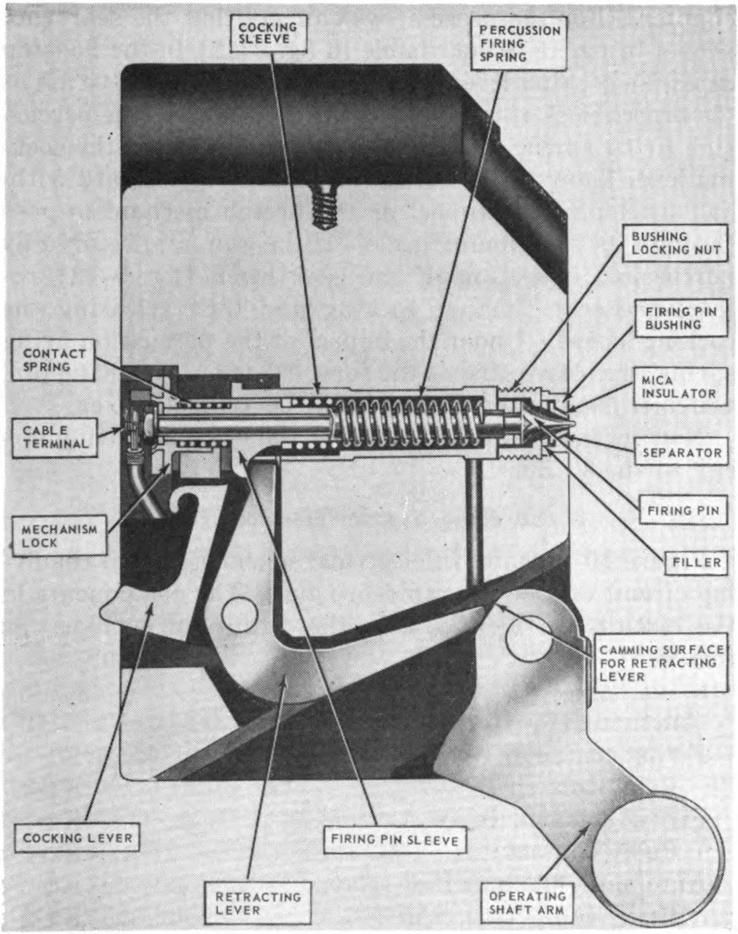


Figure 10–8.—3"/50 firing system. Firing mechanism and other breechblock parts.

cock the firing mechanism for percussion fire. All it does is retract the firing pin just before the block begins to go down; when the block goes up, the firing pin moves forward again.

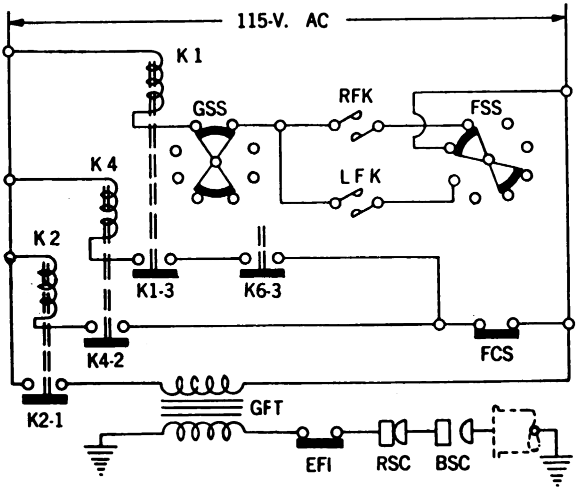
Cocking, on the other hand, takes place as the breechblock approaches breech-closed position. The process is discussed and illustrated in detail a little later in this chapter. For the present, we can say that the sear (not shown in fig. 10–8 but visible in fig. 9–12) in the housing cams the cocking lever so it pulls the cocking sleeve aft as the breechblock rises. This partly compresses the percussion firing spring. If the gun fires electrically, the cocking lever allows the cocking sleeve to move forward without developing an impact as the breech mechanism goes through its functioning cycle. If the gun is to be fired by percussion, operation of the sear lever (fig. 9–13) rotates the sear, further cocking and then releasing the cocking sleeve. Under the impact of the percussion firing spring, the sleeve strikes the forward end of the firing pin, which transmits the impact to the cartridge primer.

Now let us look more closely at the electrical firing circuit of the 3"/50.

3"/50 Firing System: Electrical Firing

Figure 10–9 shows in electrical schematic form the firing circuit of a 3"/50 rapid-fire gun. The components in the circuit are identified in the figure by symbols, as follows:

Name	*Symbol*
Gun firing transformer	GFT
Firing contactor relay	K1
Relay contact	K1-3
Firing solenoid relay	K2
Relay contact	K2-1
Automatic fire interlock relay	K4
Relay contact	K4-2
Relay contact (for gun captain's control relay)	K6-3
Electric firing interlock switch	EFI
Breechblock drop sliding contact	BSC
Gun recoil sliding contacts	RSC
Firing stop switch	FCS
Gun selector switch	GSS
Firing selector switch	FSS
Local surface firing key	LFK
Local AA firing key	RFK



NOTE: Selector GSS on Twin-Gun Mount Only

Figure 10–9.—3"/50 firing system. Electrical firing schematic.

In this diagram (as in BuOrd electrical schematic diagrams generally) solid lines indicate electrical connections and dashed lines indicate mechanical connections. Thus, energizing K1, K2, K4, and K6 (whose coil is in another circuit not shown in fig. 10–9) closes their contacts shown in the figure. RFK, LFK, GSS, and FSS are operated by crew members. And one side of GFT and the cartridge case are grounded.

As you can see from study of the schematic, the firing circuit components are so arranged that the GFT primary current, which comes from the loader control system, is closed through relay contact K2-1 of the loader control system. And by tracing the circuitry in figure 10–9 you can see that K2 can be energized only when a series of other contacts, interlock switches, and firing keys is closed. Thus the firing transformer is not even energized until the loader is ready and the firing keys and selector switches are closed.

There is a similar series of safeguards in the secondary circuit. This circuit has as its current source the secondary of the gun firing transformer (20 v). It is a one-wire system grounded through a cable lug and ground strap on top of the loader main housing. It completes its circuit at the other extreme by contact of the firing pin with the primer. Three safety switches are in this circuit. One (EFI) is an electric firing interlock switch of the loader control system; it closes when the transfer tray of the gun loading mechanism completes its loading cycle. (Fig. 10–10 shows the tray in position to close EFI.) The other two safety switches, RSC and BSC, are contacts that respectively close only when the gun is in battery and the breech is closed.

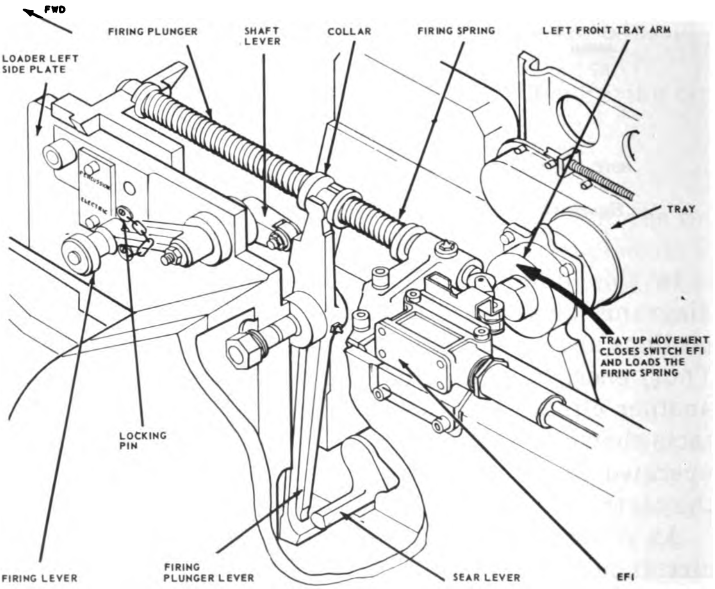


Figure 10–10.—3"/50 firing system. Firing components on the loader.

Thus, by including these protective devices in both the primary and secondary circuits of the firing system, the primary is controlled by both automatic and manually operated devices, while the switching in the secondary circuit is completely automatic.

One of the main differences between the earlier hand-rammed semiautomatic 3"/50's and their rapid-fire successors (Mk 27 and later mounts) is that the former fired percussion-primed ammunition, while the rapid-fire mounts use electric-primed ammunition. (Earlier mods of the RF mounts were first designed to fire percussion-primed ammunition, but all have by now been modified for electrical firing.) When such a round misfires, you can't (as you would on a 5"/38 using combination-primer ammunition) just shift to percussion fire and try again. Misfire procedures for a 3"/50 requires that after laying the gun on a safe bearing and opening the firing circuit at GSS (see fig. 10–9), you trip the salvo latch, carefully open the breech by hand, extract the misfired round, and dispose of it. Then you recycle the loader to load a fresh round.

Note that this procedure does NOT provide for percussion fire. If that's so, when DO you use percussion fire?

The answer is that you need it when, as you extract a misfired 3"/50 service round, the cartridge case comes out but the projectile stays in the chamber. If this happens, you hand-ram a percussion-primed short case, close the breech by hand, and operate the electric-percussion lever to fire the gun. Let's now look into the functioning of the percussion-firing mechanism itself.

We have already studied the percussion firing components in the breechblock (fig. 10–8). Figure 10–10 shows the percussion firing components in the left side plate of the loader. Figures 9–12 and 9–13 respectively show the parts between the breechblock and the loader side plate—namely, the sear lever and sear piston on the side of the gun housing, and the inside end of the sear in the middle of the housing. After you have looked at these illustrations once more, carefully, you can see how the percussion firing components in the loader are mechanically connected with those in the breechblock, and we can go ahead to follow them through a percussion firing functioning cycle.

You can trace this mechanical connection by starting with the firing lever (fig. 10–10). This is a two-position control normally set at ELECTRIC, as shown in the figure. The firing lever positions the shaft lever. This in turn engages the firing plunger lever, whose lower end is therefore held away from the sear lever when the firing lever is at ELECTRIC. The firing plunger lever upper end engages a sliding collar, which is held between two springs on the firing plunger lever.

When, as shown in figure 10–10, the loader tray is in its uppermost position (which is the position in which it is clear for firing), it closes the electrical firing interlock switch (EFI) to permit electrical fire, and pushes the firing plunger forward to permit percussion fire. Pushing the plunger forward compresses the firing spring. When the firing lever is pushed up to PERCUSSION, the shaft lever moves down and releases the firing plunger lever. The firing spring then expands, pushing the firing plunger lever upper end forward and its lower end aft. The lower end rotates the sear lever, and this in turn rotates the sear and actuates the cocking lever to cause the firing pin to deliver an impact to the primer. (Follow these actions in fig. 9–12 and 9–13.)

This action is somewhat complex, so let's follow through again in more detail. We begin with the loader and slide parts of the firing system in the positions shown in figure 10–10, and the parts in the breechblock as in figure 9–13. The short case has been loaded and the breech is fully closed. Now you disengage the locking pin on the left side plate of the loader to unlock the firing lever, and you push the lever up to PERCUSSION position. This causes the shaft lever to release the firing plunger lever. The firing spring rotates the lever so that its lower end turns the sear lever, and the sear turns.

It's time to look inside the breechblock again (fig. 9–

13). As the sear turns (the arrow in fig. 9–13 shows the direction of rotation), it rotates the cocking lever to retract the cocking sleeve. This movement also loads the percussion firing spring in the firing mechanism in the breechblock. Then, as the sear continues to rotate, it suddenly releases the cocking lever. The result is shown in figure 10–11A. The cocking sleeve is driven forward and the cocking lever is rotated, and the impact of the cocking sleeve on the firing pin sets off the primer.

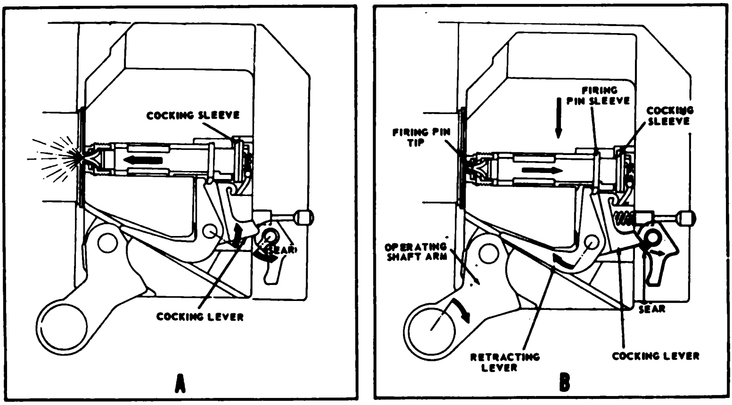


Figure 10–11.—3"/50 firing system. Percussion firing. A. Firing action. B. Retraction of firing pin and resetting of sear.

The gun fires, recoils, and counterrecoils. As the breechblock begins to drop, the operating shaft arm cams the retracting lever to pull back the firing pin sleeve, thus retracting the firing pin. At the same time, the descending cocking lever tip engages and rotates the sear. (Both actions are shown in fig. 10–11B.) After the breechblock has passed, the spring-loaded sear piston (visible in fig. 9–12 but not in 10–11B) restores the sear to the position it was in before the cycle began.

PRECAUTIONS. In percussion firing, besides the usual misfire, cook-off, slide locking, and loader shut-off precautions mentioned earlier in this chapter, note the following:

1. When the short case has been fired, reset the firing lever at once to ELECTRIC, and lock it with the locking pin.
2. Unlike the 5"/38, in which, as you will shortly see, the firing mechanism functions to prevent percussion as well as electrical fire, the firing stop mechanism in the 3"/50 interrupts electrical firing only. For this reason it's doubly important to be sure the gun is on a safe bearing when firing in percussion.

FIRING STOP MECHANISMS

A long-range, heavy weapon like a turret gun or dual-purpose gun can do a number of things that a small weapon like a rifle or a caliber .50 machine gun cannot. It can strike a target at a much greater range. It can wreak much greater destruction on that target. And, unfortunately, it can much more easily direct destructive fire on the vessel aboard which it is mounted.

The reason for this is that in heavy weapons the gun bore axis can diverge considerably from the line of sight to the target. Especially in enclosed mounts where field of view is considerably restricted, a line of sight that looks perfectly clear through the sight telescope may have the gun bore axis right in line with the ship's superstructure, an adjacent mount, a stack, a mast, or a radar antenna. The fire-control director, radar and all, cannot prevent this, nor can the computer or the on-mount sights. In anything bigger than a light machine gun installation, firing into your own ship must be prevented AUTOMATICALLY.

This can be done in several ways. One is to limit mechanically how far the gun can be depressed. This is done on many 20-mm mounts; the depression limit is determined by a big circular cam surrounding the mount and the gun cannot be depressed to fire into the ship. Another is to build into the mount power drive provisions for elevating the guns above obstacles on the ship when the mount is trained inboard; there are on some carriers 5-

inch mounts that can be equipped with this feature. But by far the commonest is to prevent the gun from firing in any position in which the bore axis passes through some part of the ship. This is done by a FIRING STOP MECHANISM.

Elements of a Typical Firing Stop Mechanism (5"/38)

In all gun mounts from 40-mm to 5-inch the firing stop mechanisms are all pretty similar in principle, though you will find differences in the linkage connecting the firing stop mechanism to the remainder of the firing system. Also, in rapid-fire 3"/50 mounts the firing stop mechanism interrupts only the firing circuit, and has no effect on percussion fire. In 40-mm and 5-inch mounts the firing stop mechanism can prevent both electrical and percussion fire.

The main components of the firing stop mechanism are shown in figure 10–12A. The heart of it is the FIRING STOP CAM PLATE (fig. 10–12B).

The firing stop cam plate is a metal disc whose surface is partly cut away (fig. 10–12B). A spur gear linked to the train mechanism engages the cam gear and turns it as the gun mount trains (fig. 10–12A). Crossing the cam is the ELEVATION INPUT SHAFT, which moves toward the center of the cam plate when the gun elevates, and outward from the center when it depresses. At the lower end of the elevation input shaft is the FIRING STOP PLUNGER, whose lower end rides on the surface of the cam.

Every point the plunger touches on the surface of the cam corresponds to a specific position of the gun in elevation and train, and to that position only. As the cam plate moves with gun train and the elevation input shaft moves the gun elevation, the plunger similarly moves over the cam surface. When it is riding on a low part of the cam surface, the plunger rides low; when it rides onto a raised part, it moves up.

The firing stop mechanism we'll look at as an example is from a 5"/38 mount. Figure 10–13A shows its exterior,

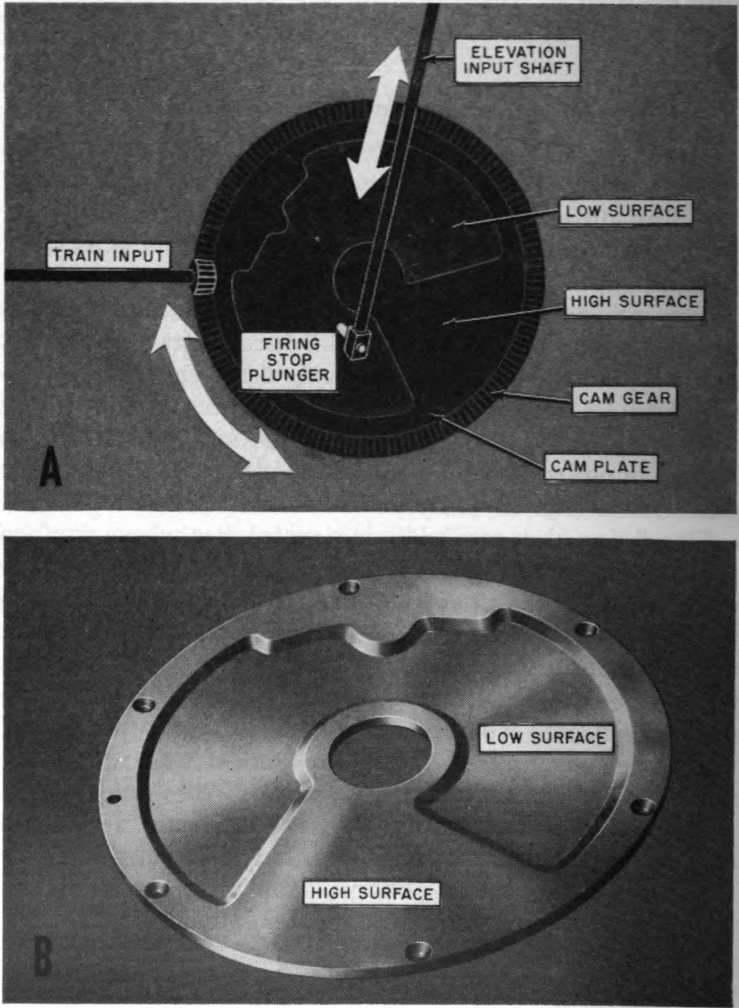


Figure 10–12.—Principle of the firing stop mechanism. A. Main components. B. Firing stop cam plate.

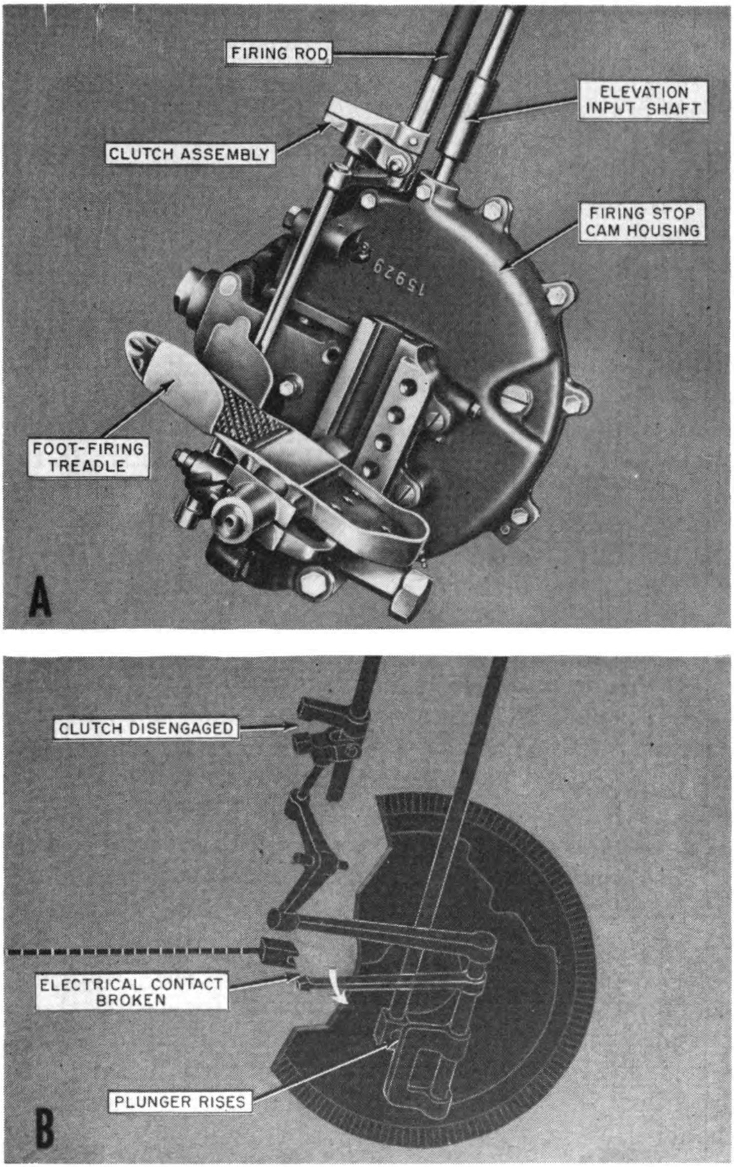


Figure 10–13.—Firing stop mechanism for 5"/38 mount. A. Exterior. B. Functioning to interrupt fire.

and 10–13B shows what it does in interrupting fire. However, the differences among 40-mm, 3-inch and 5-inch mechanisms lie in details of linkage connections to the firing system and to elevation and train gear, and in electrical details. Otherwise all are similar, even in location. (All firing stop mechanisms are located on the carriage structure of the mount.)

The firing stop cam plate is so cut that the low places correspond to positions in which the gun may safely be fired; the high places to gun positions in which the axis of the gun's bore passes through parts of the ship's superstructure, deck, masts, etc. The ability of the gun to fire is controlled by the position of the plunger. When it is in a low area of the cam plate, and rides low, the gun can fire; when it rises, it breaks an electrical contact in the firing circuit and disengages a clutch in the foot-firing linkage, preventing both electrical and percussion fire (fig. 10–13B). Just where fire is permitted and where it is prevented depends on how the firing cutout cam is cut.

Testing Firing Stop Cams

The firing cutout mechanism is vital to the safety of both ship and crew. Gunner's Mates don't normally cut the cam, but your chief or GM1 is responsible for plotting the cut and testing the cam after installation. On smaller guns you may be assigned to assist in this work under his supervision.

First look up and study the instructions on installing and orienting the cam. (See OP 0 on this.) After installation you check the accuracy of the cam profiles and the adjustment of the firing stop mechanism. Here is a suggested procedure, using a voltmeter for electrical circuit checking. (An electric lamp of correct voltage rating —usually 24 v—can be used instead of a voltmeter.) The procedure is to be used also for the daily firing system check. Here it is:

1. Make sure that the gun is NOT LOADED.
2. Lay the gun so that it is OUTSIDE of a danger zone.

3. Complete the firing circuit as for local firing.
4. Connect the voltmeter or lamp between the firing pin and ground. (See the section on firing system maintenance later in this chapter for fuller details on electrical firing circuit testing.)
5. The voltmeter will indicate full firing circuit voltage, if the circuit is completed properly (as it should be).
6. Position the gun so that it is WITHIN a danger zone. The voltmeter should now read zero.
7. Train and elevate the gun in and out of the firing zone at various points. Check to see that the operation of the firing stop switch, as indicated by the voltmeter, occurs at the proper points.
8. If percussion firing is also included in the cutout mechanism, check to see that the percussion firing mechanism cuts out whenever the switch in the firing circuit opens.

If a voltage is present in step 6, or during step 7 when the gun is in a danger zone, FIRST check for a defective firing stop switch, a defective or short-circuited plug, or faulty cable installation. If they check out OK, then you may suspect the firing stop cam layout.

Before you make ANY changes in the installation, see your responsible GM1 or GMC. Such changes must be approved by the gunnery officer.

Firing Stop Mechanism as a Safety Device

The firing stop mechanism is a safety device. Naturally, it can go wrong, but nobody should bypass it unless he's SURE it isn't doing its duty. And that means actually verifying that the gun is on a safe bearing. To point up this warning, here are two paragraphs from a Navy directive of a few years back:

"A serious casualty resulted when a 5"/38 cal. twin mount on a battleship fired into an adjacent mount, in spite of the firing stop mechanism being in good operating condition. This occurred during the heat of a night engagement. With its guns elevated about 8°, the mount had been trained into the forward stop without the mount personnel realizing it. It received the order 'COMMENCE FIRING.' But proper functioning of the firing stop mechanism prevented firing either electrically or by the pointer's foot firing pedal.

"One sight setter was also a mount striker, and hence was specially familiar with a method of bypassing the firing stop mechanism. He erroneously assumed the mount was on a safe bearing and that there was only some firing circuit 'failure.' In excess of zeal to recommence firing and without references to others in the mount, he fired the guns by manually operating the clutch lever of the firing stop mechanism."

Ordalts have been issued to make it more difficult to tamper with the firing stop mechanism in this way, but even an Ordalt is no substitute for cool common sense. Before you tamper with a firing mechanism, KNOW what you're doing.

FIRING SYSTEM MAINTENANCE

By now you have an understanding of the importance of gun firing systems—their importance both with regard to the efficiency of the guns they are part of, and with regard to the safety of your own ship and crewmates. These systems are DESIGNED to be efficient and safe, and it's up to you to KEEP then efficient and safe. And this, as you have no doubt guessed, means maintenance.

Let's go over some of the main aspects of gun firing system maintenance.

Testing

Checking the firing mechanism of a naval weapon is one of the items that you'll find listed under "Daily" on the check-off list. It will involve two phases—checking the functioning of the firing mechanism proper, and checking the firing-stop mechanism. We've already discussed firing-stop mechanism checking, so let's go on to the firing mechanism, using that familiar example, the 5"/38.

On the 5"/38 (as on all naval weapons except small arms and machine guns under 3-inch) the firing mechanism or firing lock is easily and quickly removed from and installed in the breechblock without disassembly. The firing mechanism or lock is normally kept in its place in the block. It is ordinarily replaced with a freshly cleaned and overhauled unit weekly, and before every day of firing. You will do a good deal of disassembling, cleaning, overhauling, and reassembling of firing locks aboard ship.

However, though this insures that the firing mechanism is in reliable working order, there's more to the over-all firing system of the gun than that. The guns you'll deal with have either electrical firing systems, percussion firing systems, or a combination of both. So, after you've installed a fresh firing lock, you still have to test the firing system as a whole.

There are two things to test in the electrical firing system:

1. Its CONTINUITY—that is, does the electrical firing impulse get through to the firing pin?
2. Its INSULATION—that is, does the electrical firing impulse leak through the insulation so that it either is weak or completely fails to reach the firing pin?

Continuity and insulation can be tested without loading the gun.

The continuity test is done with a small test lamp which has two insulated leads with metal tips. Hold one tip against the terminal of the firing pin and the other against an unpainted dry spot on the slide or housing. (This is called GROUNDING the lead.) When the firing key is closed, the lamp should glow. (See fig. 10–14A.)

This test should be made on both the motor-generator circuit from the director and on the local battery circuit. The gun must be positioned in a direction in which it is safe to fire. You will find that the lamp will glow more brightly on the motor-generator circuit, but you should also get a definite glow from the battery circuit. If you

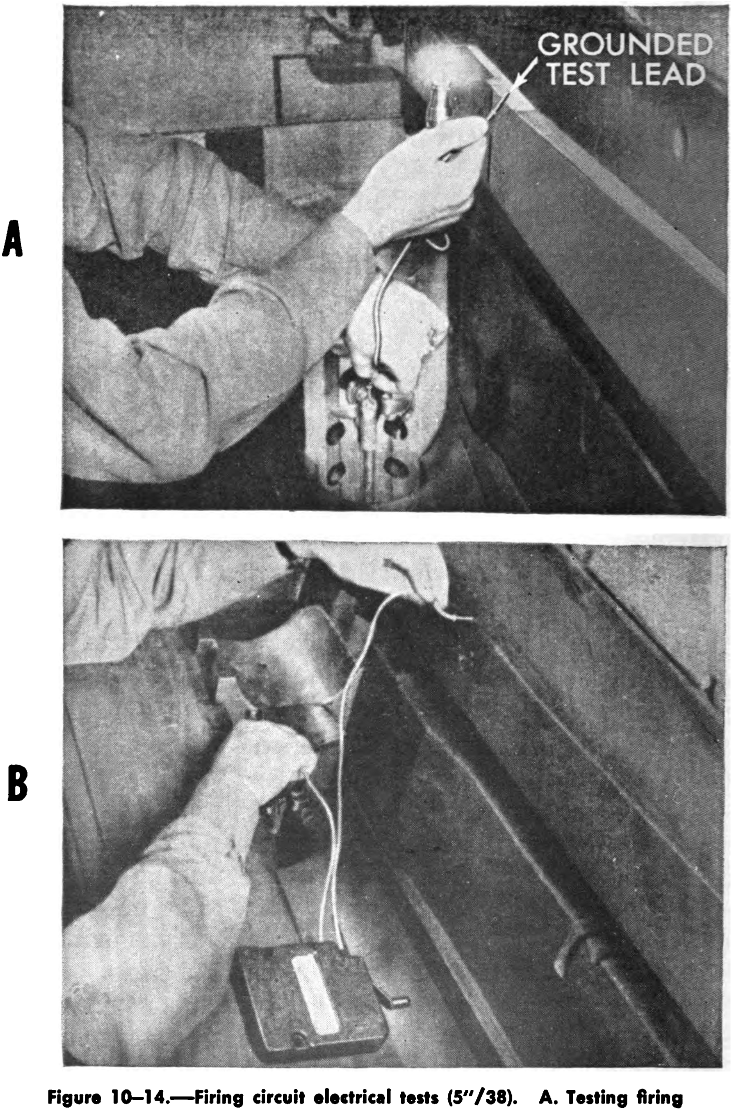


Figure 10–14.—Firing circuit electrical tests (5″/38). A. Testing firing circuit continuity with test lamp. B. Testing firing circuit insulation with megger.

don't get results like these, there's trouble in the firing circuit.

The insulation test involves the use of a MEGGER—an electrical measuring instrument that indicates the resistance of insulation. To make this test, attach one lead of the instrument to the firing terminal and ground the other. (See fig. 10–14B.) Then turn the handcrank of the megger. The needle on the instrument should indicate at least one megohm. If the reading is lower, inspect the insulation of the wiring in the firing circuit. Most commonly, when there is insulation failure, it takes place in the firing lead, and that is where you should look first for bare wires, frayed insulation, and so on. Always inspect the firing lead, regardless of test results, to be sure that it isn't kinked, doesn't foul some part of the gun, and hasn't any oil or grease on it.

The only way to test percussion firing is actually to fire a primer. Since the purpose of firing is simply to make enough noise to indicate that the firing mechanism is functioning properly, a complete service round with projectile and full propelling charge is unnecessary. You therefore use a special TEST CASE and a TEST PRIMER. The case has a primer hole into which the test primer fits.

Here is how the test is made:

1. Aim the gun in a safe direction. Remove the tompion or muzzle cover.
2. With the operating handle of the gun, lower the breechblock all the way. Stow the handle.
3. Insert the test case (with test primer mounted) into the chamber and ram it home by hand.
4. Depress the foot firing pedal. You should hear a distinct bang as the test primer is detonated. If you don't, first make sure that the firing cutout is not the cause of failure by training and elevating to another position in which you know the gun is supposed to fire safely. You can verify this by watching the firing shaft that connects the firing stop

mechanism to the trunnion. It should turn as the foot firing pedal is depressed. If it does, and the test primer still doesn't fire, you have a malfunction in the firing linkage or mechanism to deal with.

5. If the primer tests OK, open the breech and remove and stow the case. Replace the tompion or muzzle cover.

Test primers are used also in testing electrical firing, to supplement the test lamp and megger checks described above.

Care and Adjustment

In addition to daily testing (or testing before firing) of firing systems, you have to disassemble, clean, lubricate as necessary, and reassemble the firing mechanism of each gun mount on the ship. Check-off lists call for removal, disassembly, cleaning, and reassembly of firing mechanisms after every firing, as well as daily. While the firing mechanism is out of the breechblock you inspect, clean, and repair as necessary all firing contacts, interlocks, and other elements of the firing circuit as required by the OP. Look for loose connections, oil-soaked or frayed insulation on firing cables, and other signs of possible future trouble, and make the replacements or repairs necessary for heading them off.

Check mechanical parts of the firing system (generally those associated with percussion firing) for proper lubrication, and for excessive wear, galling, sticking, or other trouble symptoms.

Remember that, in general, lubricant is to be kept OFF all electrical parts, from switch contacts to cables.

Firing mechanisms for 5-inch guns should be disassembled and cleaned in alcohol, then wiped clean. Be sure the firing pin tip is free of lubricant, and that the terminal on the pin after end is capable of making sure contact. Check the springs to see that they have not set. Before replacing the firing mechanism in the breechblock bore, see that the bore is clean. Oil very lightly the firing plunger of the mechanism.

Much the same treatment should be accorded the 3"/50 firing mechanism, except that alcohol should NOT be used as a cleaning agent. Alcohol will destroy the wrapped and shellac-coated insulation of the firing pin. Use solvent PS-661 instead. After cleaning is done, put a very light coat of oil on the cocking sleeve and the outside of the firing pin sleeve, then reassemble.

SUMMARY

In this chapter we have studied the firing mechanisms of several naval gun mounts, and this included, besides the firing mechanism parts in the breechblock, electrical firing circuits and percussion firing linkages elsewhere in the mount. We also studied the principles and testing of firing stop mechanisms, and concluded with a section on the maintenance of firing systems.

The next chapter is concerned with recoil and counter-recoil systems of naval guns.

QUIZ

In each of the following multiple-choice questions, select the ONE best answer.

1. Except for emergencies and under special circumstances, the firing current for naval guns is supplied to the cartridge primer at
   a. 115 to 125 v a-c or d-c
   b. 20 to 24 v a-c
   c. 230 to 250 v 3-phase a-c
   d. 6 to 8 v d-c
2. In the 5-inch mount firing system, which of the following firing circuit elements is NOT in series with the primer?
   a. Firing snap switch
   b. Pointer's key
   c. Firing stop switch
   d. Remote firing key
3. By using his firing snap switch, the pointer on a 5-inch mount, can select between
   a. local battery fire and motor-generator fire
   b. local control and remote control
   c. percussion fire and electrical fire
   d. remote key fire and pointer fire
4. Select the item that plays NO part in electrical fire of a 5"/38.
   a. Firing pin
   b. Firing terminal
   c. Firing spring
   d. Primer
5. The contact spring holds the firing pin in the 5"/38 firing mechanism firmly against the primer in order to
   a. provide good electrical contact
   b. transmit the blow of the firing plunger more effectively
   c. prevent the point of the pin from being bent when the breechblock moves
   d. keep the firing pin from vibrating or working loose.
6. On a 5"/38 mount, when the pointer steps on the foot-firing treadle,
   a. the sear is rotated counterclockwise
   b. the trip plate pushes the inner push rod in the center of the trunnion
   c. the firing rod lever pushes the outer push rod
   d. an electrical impulse passes through the firing pin
7. In the 3"/50 firing system, which of the following cocks the firing mechanism for percussion fire?

a. Cocking sleeve
b. Cocking lever
c. Retracting lever
d. Sear lever

8. Which of the following elements of the 3″/50 firing circuit has one side grounded?
   a. Transformer GFT
   b. Switch EFI
   c. Switch GSS
   d. Coil of relay K4
9. In the 3″/50 firing circuit, the primary of the firing transformer is in series only with
   a. switch GSS
   b. switch FCS
   c. contact K2-1 of relay K2
   d. the coils of relays K-2 and K-4
10. In the 3″/50 percussion firing system, the firing plunger compresses the firing spring when
    a. the firing lever is moved to PERCUSSION
    b. the firing plunger lever cams the sear lever
    c. the shaft lever releases the firing plunger lever
    d. the loader tray is in firing position
11. In the 5″/38 firing stop mechanism, the firing stop plunger moves inward, toward the center of the firing stop cam plate, as the gun
    a. elevates
    b. depresses
    c. trains clockwise
    d. trains counterclockwise
12. Which of the following maintenance tips is NOT applicable to 3″/50 firing system components?
    a. Keep oil off firing leads and firing contacts
    b. Disassemble and clean the firing mechanism with alcohol
    c. Test firing circuit insulation with a megger
    d. Use a light film of oil on parts in the firing mechanism that move in percussion firing.

CHAPTER 11

RECOIL AND COUNTERRECOIL SYSTEMS

INTRODUCTION

Newton's third Law of Motion states: "To every action there must be an equal and opposite reaction." Which means that if you push something, it exerts an equal and opposite push on you. In gunnery, it means that the thrust that hurls the projectile on its way is matched by an equal thrust, in the opposite direction, on the gun.

This should not be new to you. When you've fired small arms, you've actually felt the kick of recoil. And all guns have that recoil kick. The more powerful the propelling charge, and the more massive the projectile, the stronger the recoil force potentially is.

A hundred years ago, recoil in large naval guns was not only inevitable but a nuisance. You probably remember, from the preceding course in this series and from such sources as historical novels and pictures of sea combat of a hundred years ago and more, how the Gunner's Mate of olden times used to scramble out of the way to avoid the murderous recoil of his clumsy cannon. Then, after the shot was fired and the gun was reloaded, he and his mates had to fall to and haul the gun back into battery, in position for firing again. In combat, with a gun as clumsy as it was massive, and on a rolling deck, that was no mean task—or perhaps we should say it was mean, very mean.

Methods of Controlling Recoil

In modern gun mounts recoil is controlled, is made to work for the gun crew, and, in some more recent developments, can be eliminated altogether. The devices that have been used on modern gun mounts to control recoil forces are:

1. Recoil mechanism (also called recoil brake).
2. Counterrecoil mechanism.
3. Muzzle brake.
4. Vented breech (used with special propelling charges).

Naval guns use only the first two of these devices, so we can say only a little here about the others. A muzzle brake is a set of baffles screwed to the gun muzzle. You'll see them commonly on Army tank guns. When the gun fires, the muzzle brake deflects some of the propellent gasses that follow the projectile out of the bore so that part of the force of their blast tends to pull the gun barrel forward, opposing the main backward force of recoil. The vented breech is also a propellent gas deflecting device. It completely eliminates recoil and counterrecoil systems. It's used with special perforated-case propelling charges; when they go off, part of their blast is directed backward and completely balances the recoil thrust. With no recoil or counterrecoil systems, large-caliber guns can thus be made light enough to be used by infantry.

Muzzle brakes reduce the recoil thrust and the vented breech eliminates it altogether. However, neither device has so far been used in naval weapons aboard ship, though they conceivably might be in the future. Both devices in their present form are dangerous to personnel in the vicinity, other than the gun crew, and the vented breech device can be used only on open mounts. Moreover, a gun with vented breech has much less range than a conventional mount of equal caliber.

This chapter is therefore concerned only with recoil brakes and counterrecoil mechanisms. In any gun these systems work together; when we take them up separately, it's only to simplify the explanation. As elsewhere in this course, we'll depend on the familiar 5"/38 as a prototype for explaining the principles of the mechanisms and to show the main design features, but we'll also take up other designs that are important for you to know.

RECOIL MECHANISMS

In all naval gun mounts 40-mm and larger you'll find hydraulic mechanisms used as recoil brakes. Smaller weapons like 20-mm or caliber .50 machine guns use mechanical buffers and springs to control recoil thrust. Small arms, although they use the energy developed by the burning propellant in the form of recoil thrust as well as in other forms to operate their mechanisms, have no recoil brakes or counterrecoil systems as such.

Hydraulic recoil brakes function to "spread out" over an appreciable time period the almost instantaneous recoil thrust produced upon firing. Recoil thrust is transmitted by way of the gun slide, carriage, and stand to the ship's structure. By spreading it out, the recoil brake reduces the maximum instantaneous recoil thrust that these components must be designed to withstand. This saves material and reduces the ship designer's eternal problem of topside weight.

The recoil brake also absorbs a considerable amount of the energy produced in recoil. The energy absorbed goes to heat up the recoil fluid in the system. Energy not absorbed by the recoil brake is stored in the counterrecoil system (to be discussed later in this chapter) and is used in moving the recoiling parts back into battery.

Throttling Groove Type Recoil Brake (5"/38)

Let's now look more closely at the recoil system used in 5"/38 mounts.

The 5"/38 recoil system consists mainly of two cylinders in the housing (fig. 11–1A) and two pistons secured to the slide. In the piston-cylinder hydraulic mechanisms

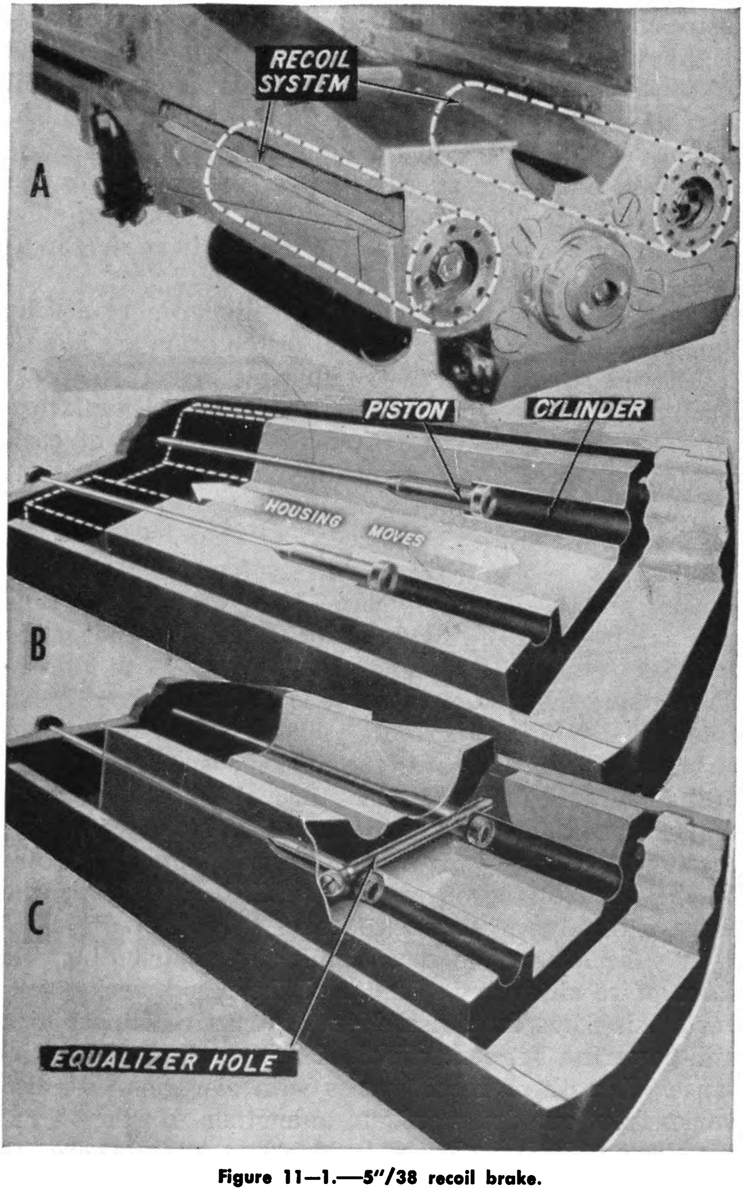


Figure 11—1.—5"/38 recoil brake.

that we've so far studied, we have generally found that the piston moves in the cylinder. With this 5"/38 recoil system, however, it's different; the piston, which is secured to the slide, stands still, while the cylinder moves in recoil with the housing, of which it is part. Keep this point in mind as we trace the functioning of the recoil system.

Parts B and C of figure 11–1 show the housing in full recoil position. The upper part of the housing and slide have been cut away. The dotted outline in part B indicates the housing's battery position.

Now let's examine the piston and cylinder more closely. Since the two recoil cylinder-and-piston units are identical, it will be sufficient to examine just one (fig. 11–2). Each cylinder is partly filled with recoil fluid (a mixture of water with glycerin). In the wall or liner of each cylinder are cut three throttling grooves (fig. 11–2), which are shallow at the forward end of the cylinder and deepen toward the after end.

When the gun is fired, the force of recoil pushes the housing and the recoil cylinders within it to the rear, thus exerting pressure on the fluid in the forward end of the cylinder. But the throttling grooves permit the fluid to flow around the piston only at a controlled or THROTTLED rate. The cylinder therefore yields to recoil thrust and moves aft, but is subject to the continuous braking action of the hydraulic fluid as it flows through the grooves from the forward end of the cylinder to the rear. Since the recoil fluid can flow only at a rate proportional to the size of the throttling grooves, the recoil brake resists the force of recoil over its entire stroke.

In effect, then, the recoil brake, by distributing the force of recoil over the length of the recoil stroke, converts this force from a sudden, destructive impact to a still-powerful, but controllable, thrust exerted over a distance. Length of recoil varies with elevation. It also varies from one design of gun to another. In the 5"/38, it's about 15 inches. In the 16-inch turret gun, where the forces involved are much greater, maximum recoil is

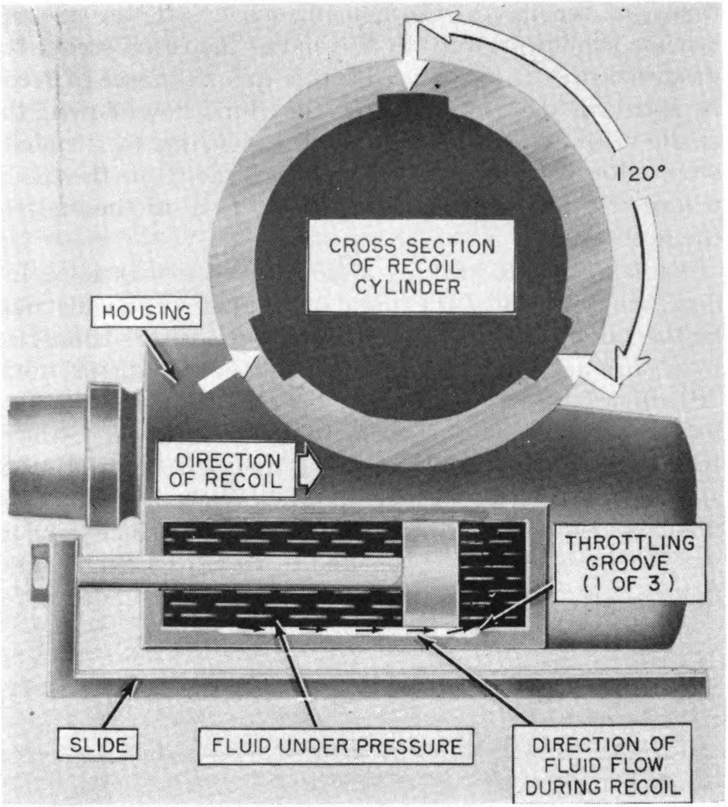

120°
CROSS SECTION OF RECOIL CYLINDER
HOUSING
DIRECTION OF RECOIL
THROTTLING GROOVE (1 OF 3)
SLIDE
FLUID UNDER PRESSURE
DIRECTION OF FLUID FLOW DURING RECOIL

Figure 11–2.—5"/38 recoil cylinder. Sectional views (simplified).

about 47 inches at full elevation. Maximum recoil of 40-mm guns is about 8.3 inches; and 3"/50 gun maximum recoil is about 12 inches. Ordnance designers prefer to restrict recoil length to save space and (in automatically loaded weapons) to improve firing rate.

Now look a little more closely at the throttling grooves and their functioning. (See fig. 11–2 again.) Note that the grooves are TAPERED. (In the figure, to show this more clearly, the size of the groove is exaggerated.) At the beginning of the stroke the grooves are comparatively deep, so that the fluid offers less resistance to the initial thrust of recoil. As the housing moves aft, the grooves become shallower, until by the end of the recoil stroke the grooves are very shallow. By this time the force of recoil is spent, and, by throttling the fluid flow down, the shallow grooves help to bring the housing to a smooth stop. Recoil movement stops just short of the point where the piston would completely close off the ends of the grooves.

To equalize the braking action of the two recoil cylinders, the pressure of the liquid in their forward ends must be the same. The cylinder heads are therefore connected by a bore across the housing, called the EQUALIZER HOLE. (See fig. 11–1C.) Through this, any difference in fluid pressure is immediately communicated between the cylinders. With this arrangement, the job of braking is shared equally by both cylinders. Without it, the cylinder developing the higher pressure (and some random variations in pressure are bound to occur) would have the lion's share of the job, and there would be a tendency for

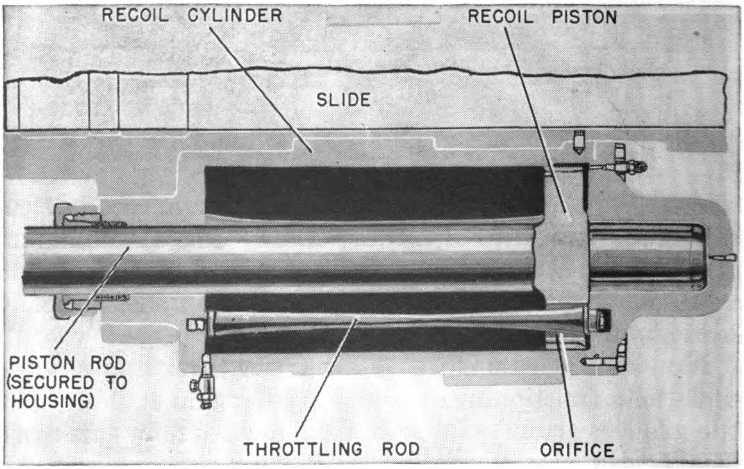


Figure 11–3.—Typical throttling rod recoil brake for a turret gun. (Simplified cross section.)

the housing to twist or slew in its ways as it moved in recoil.

After the gun housing has reached its extreme recoil position, the counterrecoil system (still to be described) pushes the recoiling parts forward into battery. During this movement, which is rather less rapid than that of recoil, the recoil mechanism plays little part until the housing nears battery position. As will be brought out later, the thrust developed by the counterrecoil system is considerable, and the forward movement of the housing must be buffed to a smooth stop. This is the function of the COUNTERRECOIL BUFFER PLUNGERS, of which there is one in each recoil cylinder. Their functioning will be described with that of the counterrecoil system; they are mentioned here because they are located in the recoil cylinders.

3"/50 Recoil Brake

The 3"/50 recoil brake is similar to that for the 5"/38 (in principle) except that it is set up so that the moving and the standing parts are opposite to those in the 5-inch system. The cylinder is bolted to a part of the slide, and the piston rod is coupled to the housing. And there is but one recoil cylinder per gun, instead of two, hence no equalizer arrangement is necessary.

All this applies to the 3"/50 rapid-fire mount. Some older pedestal-type mounts have different arrangements, but we'll not take them up here.

Throttling Rod Type Recoil Mechanism (40-mm and Turret Guns)

In turret guns and 40-mm guns you find a somewhat different application of the principle of the hydraulic type of recoil brake. Figure 11–3 illustrates in somewhat simplified form the recoil cylinder for a turret gun.

Instead of being solid, the recoil piston has three holes bored in it, spaced 120 degrees apart. Through each end of the holes passes a tapered THROTTLING ROD secured to the ends of the recoil cylinder so that it is parallel to the piston rod. (Only one throttling rod and hole are shown in fig. 11–3.) There are no throttling grooves.

As the piston moves in recoil, the fluid that it displaces can flow from one end of the cylinder to the other only through the holes. Because the throttling rod varies in diameter at different points, it blocks off a varying portion of the hole as the piston moves in its stroke. Where the rod's diameter is large, for instance, it blocks off most of the hole, leaving only a small opening for fluid flow, and the braking effect is large. Where the rod is small, on the other hand, less of the opening is blocked, and more fluid can pass, with decreased braking effect. The rods are so tapered as to provide evenly distributed resistance to recoil thrust over the length of the recoil stroke.

One advantage in the use of throttling rods is that the rods can be replaced with others of different taper if a change in the gun's recoil characteristics is desired.

Figure 11–4 illustrates a throttling-rod recoil system that's far commoner and applies the principle in somewhat more complex fashion. This one is a single-cylinder system in the 40-mm mount. The figure shows the actual sectional view of the assembly in battery position (A) and with arrows and shading to represent fluid flow during recoil (B) and counterrecoil (C).

As the barrel, housing, and loader tray recoil, the housing carries with it the recoil cylinder piston rod. As the piston rod is drawn to the rear of the recoil cylinder over the throttling rod, liquid is forced from the rear to the front of the piston through the eight holes in the piston and through the throttling bushing. Liquid pressure forces the check valve to the rear, opening the ports in the valve seat. Through these ports liquid now passes to the rear of the valve. Liquid also passes to the rear of the valve around the valve seat and through the tapered grooves inside the piston rod, through the ports in the throttling rod, over the needle valve, and through the seat. These restricted flow areas set up a fluid resistance which retards recoil.

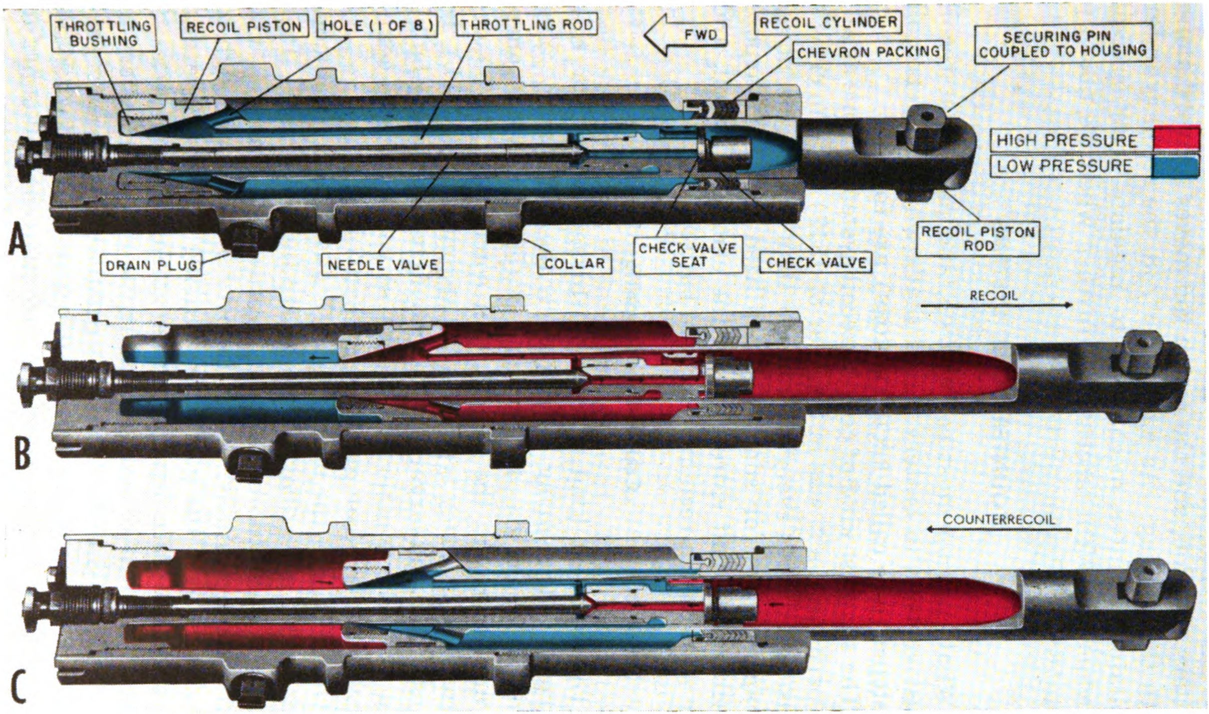


Figure 11—4.—40-mm recoil system (cross section). A. In battery. B. In recoil. C. In counterrecoil.

When recoil ceases, the recoiling parts move toward battery position, and the piston rod moves forward along with the housing. As with the 5"/38, the recoil cylinder contains a buffer mechanism to regulate counterrecoil movement. We'll discuss this further when we take up counterrecoil in the next section.

COUNTERRECOIL SYSTEMS

What goes up must come down, and parts that recoil must go back to battery. And that's what counterrecoil systems (also called RECUPERATORS) are for.

The simplest kind of counterrecoil system is none at all, or perhaps (as it was in the War of 1812) the gun crew's muscles. But in everything larger than small arms, naval weapons have for some years utilized for this purpose mechanisms that store some of the energy of recoil, and use it to return recoiling parts to battery.

Counterrecoil Springs

The simplest kind of energy storage device for this purpose is the spring—particularly the coil spring. You can see them on 40-mm and 3"/50 guns—big ones, wrapped around the barrel. (In some older 3"/50 designs, and in Army type 40's, the spring is concealed.) In guns 5-inch and larger, springs would be excessively bulky and would have other drawbacks, so you won't find counterrecoil springs on guns larger than 3-inch.

On the 3"/50 the spring is a 15½-coil helix of silicon-manganese steel alloy wire of 1.312 inch diameter. It is plated with cadmium or zinc to prevent corrosion. The coil's inside diameter is a little over 9 inches—enough to fit closely over the gun chase bearing strips on the gun chase. The free length of the spring is not quite 45 inches, but it is compressed when the gun is in battery to a length of 33 inches. At this compression, its load (expanding force) is just under 3,000 pounds. And when the spring is fully compressed, as it is when the gun is in full

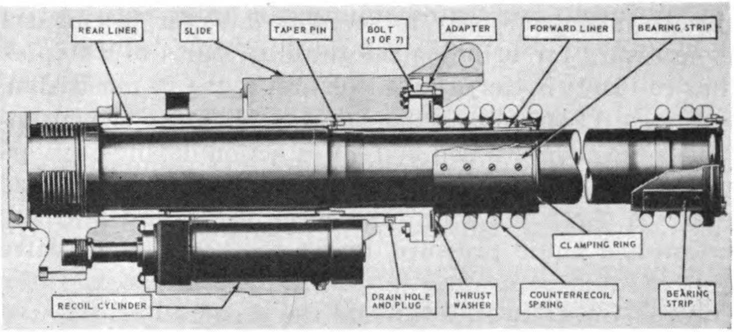


Figure 11–5.—3"/50 slide Mk 27. Counterrecoil system. Sectional view.

recoil, its load is 6,000 pounds. On Mk 26 3"/50 gun slides the forward end of the spring bears against a collar-like retainer on the gun chase, and the after end of the spring surrounds the slide front liner and bears against the forward end of the slide weldment.

With this arrangement (which in general resembles that on the 40-mm twin and quad mounts) the counterrecoil spring must be laboriously eased off ("decompressed") and removed before the mount can be regunned. Because of the force it exerts when compressed, this is a fairly elaborate and painstaking process. On Mk 27 slides, however, the design is somewhat different. (See fig. 11–5.) The forward liner of the slide can be unbolted and unscrewed from the slide and the gun barrel removed with the spring still mounted on it under full 3,000-pound compression. Regunning a Mk 27 slide is a much quicker and easier process, and spare gun assemblies can be stored complete with their counterrecoil springs, ready for quick assembly in emergency.

40-mm Counterrecoil Buffer

Unlike recoil thrust, which persists only until the projectile and the high-pressure propellent gases have cleared the gun bore, counterrecoil thrust is exerted CONTINUOUSLY on the housing, even when the gun is in battery. When you realize the thrust forces involved in a counterrecoil system, it's easy to see why a buffer mechanism is necessary for bringing the recoiling parts to a stop as they return to battery. Let's look first at the 40-mm design.

Figure 11–4C shows the recoil mechanism (which includes the counterrecoil buffer) in action during counterrecoil. As you can see, the piston rod moves forward over the throttling rod. The check valve, under spring action and liquid pressure, masks the ports in the valve seat. Liquid at the rear of the valve seat is forced to the front of the valve seat through the grooves in the piston rod and through the bore in the center of the valve seat. The tapered grooves gradually reduce the flow space as the barrel approaches battery position, until no liquid can pass over the valve seat. The flow of liquid from the rear to the front of the seat is now restricted to the bore in the seat, over the needle valve, and through the ports in the throttling rod. Liquid in front of the piston is forced through the throttling bushing and the holes in the piston.

Finally, the front end of the piston enters the recess in the head of the throttling rod. This action forces the liquid between the head and piston through the space between the throttling bushing and the throttling rod. The front taper of the rod reduces the flow space as the barrel approaches the battery position. This action and the tapered grooves inside the piston rod further reduce the speed of counterrecoil.

A buffer pad (not illustrated) on the housing provides a positive stop at battery position for the recoiling parts of the gun.

The needle valve in the buffer can be readjusted to regulate the speed of counterrecoil and hence the firing rate. Note that there is NO adjustment for speed of recoil or length of recoil (except by replacing the counterrecoil spring.)

Because the 3"/50 counterrecoil buffer closely resembles in functioning the one in the 5"/38, we needn't discuss it separately. We'll now take up the type of counterrecoil system used on all gun mounts 5-inch and larger, including turrets. Again, we'll use the 5"/38 by way of a prototype.

Hydropneumatic Counterrecoil System

The counterrecoil system of the 5-inch gun is located in the breech housing, between the recoil cylinders. Its principle operating parts are the COUNTERRECOIL PLUNGER

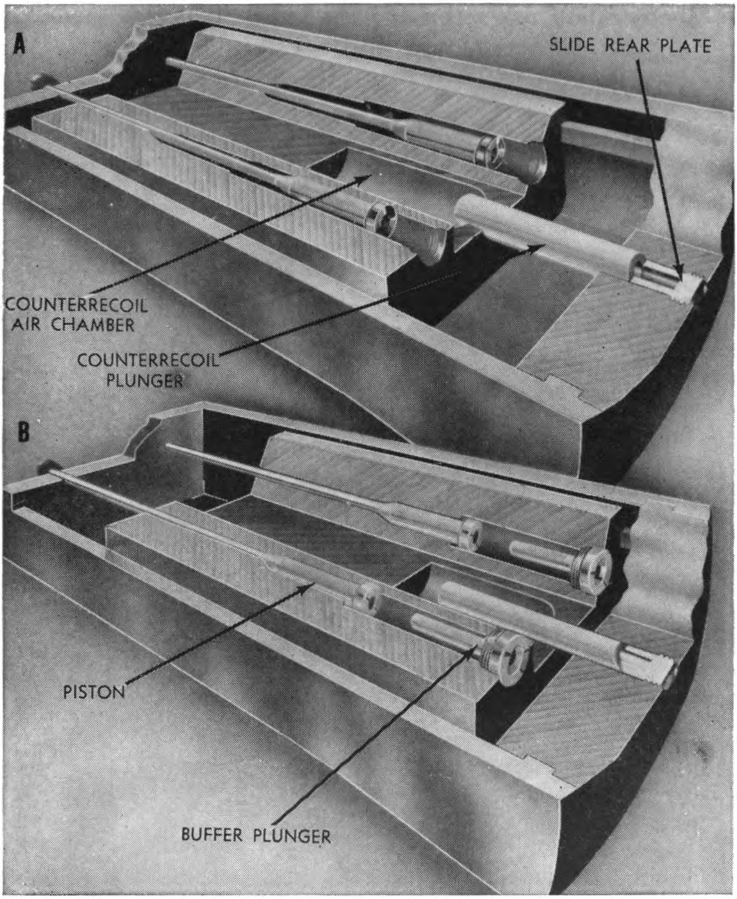


Figure 11–6.—5"/38 counterrecoil system. Cross section of housing. A. Battery position. B. Recoil position.

and the COUNTERRECOIL CYLINDER or air chamber. (See fig. 11–6.) The plunger is connected to the rear of the slide; the cylinder forms part of the housing, so that, as in recoil, it's the cylinder, rather than the plunger, that moves.

The counterrecoil system is a HYDROPNEUMATIC rather than a hydraulic device, because it contains compressed air rather than a liquid in its cylinder. The air pressure is about 1,500 psi when the gun is in battery. During recoil, the plunger moves into the cylinder, pushing the

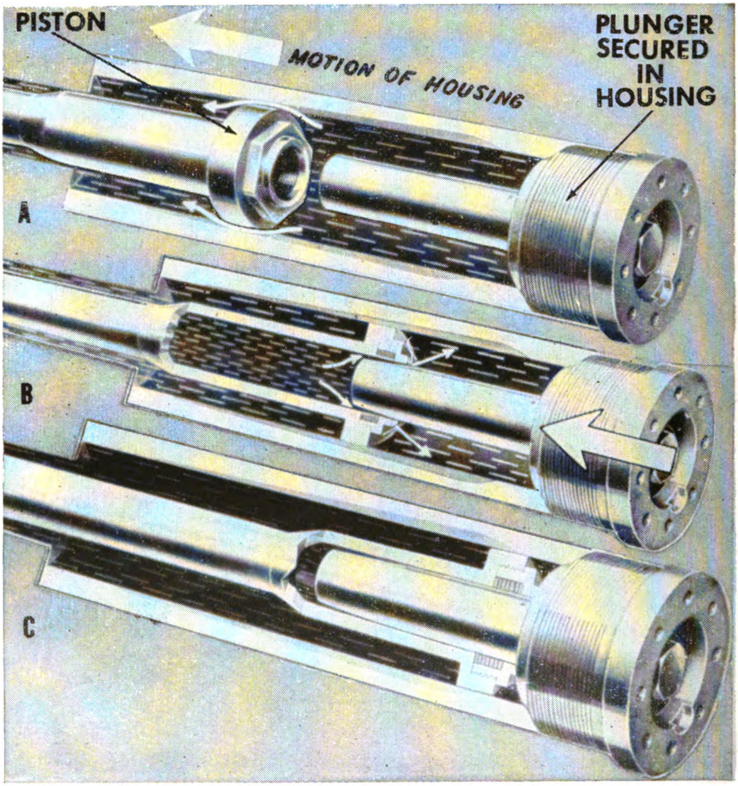


Figure 11–7.—5"/38 counterrecoil system. Functioning of counterrecoil buffer.

pressure up to 1,950 psi. This air pressure pushes the gun back into battery and keeps it there.

Now let's see how the system works. The air pressure within the counterrecoil cylinder is high to begin with. As the plunger moves in during counterrecoil, it goes still higher. In this way, the counterrecoil system stores some of the recoil energy in the form of increased air pressure. At the end of the recoil stroke, after the rearward movement of the housing has been braked to a stop, pressure of the air in the counterrecoil cylinder on the counterrecoil plunger (nearly one ton per square inch) pushes the housing and gun back into battery.

The recoil piston and the BUFFER PLUNGER in the after end of each recoil cylinder (fig. 11–6B) control the final part of counterrecoil very much as the recoil brake controls recoil—by causing its thrust to force fluid through

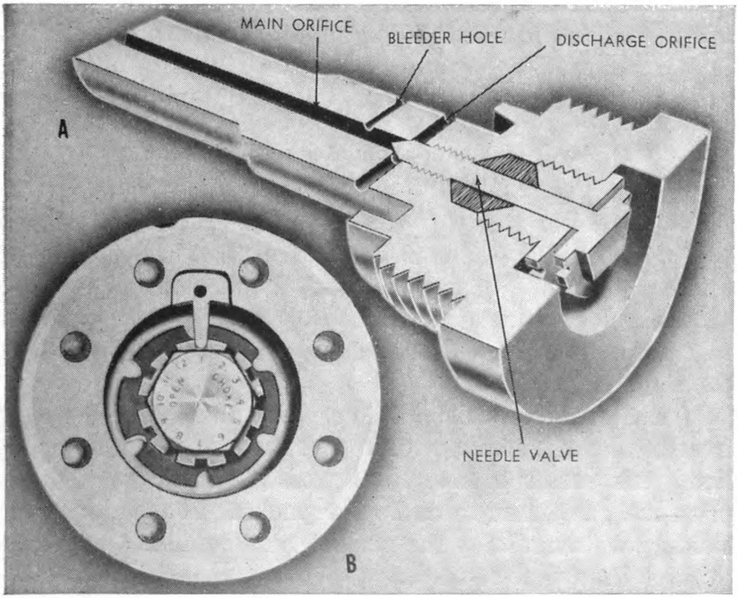


Figure 11–8.—5"/38 counterrecoil buffer plunger. A. Cross section. B. Needle valve head.

narrow openings. As counterrecoil movement begins, the housing and recoil cylinder move forward over the recoil piston. The buffer plunger, which closes off the after end of the recoil cylinder, is aligned to enter a hole in the recoil piston and piston rod. (See fig. 11–7A.) As the plunger enters the hole in the piston, the fluid caught therein is trapped, and can escape only through small passages in the plunger (fig. 11–7B). At the end of the counterrecoil stroke (full battery position), the plunger is entirely nested within the recoil piston and piston rod (fig. 11–7C).

As you can see from figure 11–8A, the flow of fluid through the counterrecoil buffer plunger is controlled by a needle valve. This valve can be set by moving its calibrated nut hexagonal top in the recoil cylinder head. (See fig. 11–8B.) By controlling the flow of the liquid through the discharge orifices or holes, the needle valve controls the speed of counterrecoil. The numbering on the calibrated valve top makes it possible to set both buffers for equal, balanced functioning. For the proper procedure in setting these valves, see the OP on the mount.

Hydropneumatic Counterrecoil System: The Differential Cylinder and Oil Seal

We have seen that, to brake the gun's recoil and return it to battery, the air in the counterrecoil cylinder must be under a pressure that approaches a ton per square inch. That high-pressure air seeks to escape past the counterrecoil plunger. You will recognize this as a problem in packing.

If the counterrecoil cylinder were filled with a liquid instead of air, packing would present no particular problem. It's easier to seal high-pressure liquid than high-pressure gas. But to make the packing seal against air leakage we must keep the packing itself under a pressure greater than that of the air.

To do this, the ordnance designer provides for the counterrecoil plunger a chevron-type packing with two opposed sets of rings (fig. 11–9A). The two sets of rings are separated by a PACKING FOLLOWER through which oil under pressure can pass.

Now let's see how this device works. Part B of figure 11–9 (which magnifies a portion of part A) shows how oil pressure is exerted against the packing. The high-pressure oil distends the packing rings, forcing them against the cylinder walls and against the counterrecoil plunger. Since, as you will see, the oil is automatically maintained at a pressure higher than that of the air, the air cannot leak out. In fact, the leakage is usually the other way

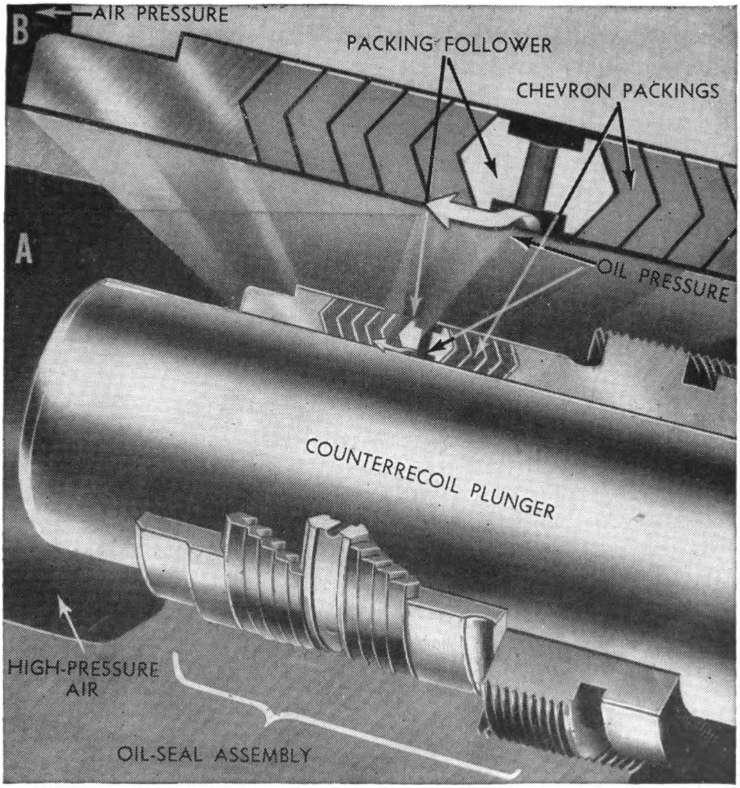


Figure 11–9.—5"/38 counterrecoil system. Counterrecoil plunger packing.

about, and precautions must be taken against the possibility of Diesel action (burning because of the presence of oxygen under pressure) between the high-pressure air in the counterrecoil cylinder and oil that may have leaked in from the packing.

To make this packing arrangement work, all we need is a source of high-pressure oil. For several reasons, a pump is impracticable; besides, there's a better way which requires less complication and no power. The answer is the DIFFERENTIAL PISTON AND CYLINDER. A setup like this ALWAYS keeps the packing oil pressure higher than the counterrecoil cylinder air pressure.

As you remember from chapter 4, a differential cylinder can produce different pressures from opposite sides of its piston while the system it is connected to remains in equili-

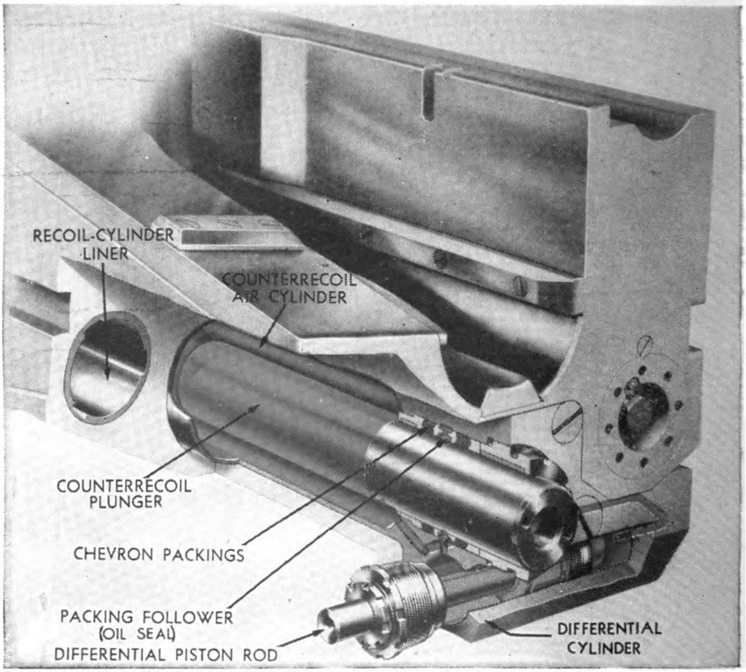


Figure 11–10.—5"/38 counterrecoil system. Differential system.

brium. It must do this, in fact, so that the opposing pressures on the piston will develop equal thrust. If, instead of having an all-liquid system, we use air on the large-area low-pressure side and oil on the small-area high-pressure side (where the piston rod is), we have a system in which the air pressure must always be lower than the oil pressure so long as the system has sufficient air to operate it and oil to seal it.

That's exactly how the counterrecoil plunger seal is supplied with high-pressure oil in the 5"/38 and other counterrecoil systems. As figure 11–10 shows it, blue indicates air and red indicates oil. The oil seal, which encircles the counterrecoil plunger, is connected to the small-area side of the differential cylinder; the counterrecoil cylinder air space is connected to the large-area side of the cylinder.

Note the piston rod protruding from the differential cylinder head. When the oil runs low, the piston is pushed farther over toward the oil side of the cylinder, and the piston protrudes, as you see it in the figure. When the counterrecoil system is charged with oil, the piston is moved toward the air side of the cylinder, and the rod moves inward. When it is approximately flush with the cylinder head, the piston rod indicates that the differential is fully charged.

MAINTENANCE OF RECOIL AND COUNTERRECOIL SYSTEMS

As you can see by reference to the Qualifications for Advancement in Rating, you're not responsible for knowing all the details of recoil and counterrecoil system maintenance until you're ready to strike for GM1. In fact, these systems are considered so vital that certain operations (most important, charging of recoil cylinders) may, by regulation, be carried out only in the presence of an officer.

For this reason, we're not going to take up here most of the maintenance operations associated with recoil and counterrecoil mechanisms. However, we shall go into two small maintenance inspection jobs that you can do, namely:

1. Checking counterrecoil system oil level.
2. Checking recoil system fluid level.

Recoil Systems

As a gun fires and moves in recoil and counterrecoil, the recoil energy absorbed by the recoil system is converted to heat. As its temperature goes up, the recoil fluid expands. If there is too much in the cylinder to begin with, the excess will tend to bleed out around the filling and vent plugs, or an undesirable pressure may build up inside the cylinder. Unlike counterrecoil systems, hydraulic recoil brakes are designed to operate at atmospheric pressure. When a recoil system is overfilled, pressure built up by overheated recoil fluid may become great enough to start a leak somewhere in the system, or cause binding or straining of parts, or other malfunctions.

Insufficient recoil fluid can also be harmful, though the effects will be different. The main effects of insufficient recoil fluid are overlong recoil and slamming of the recoiling parts both in recoil and (because of impaired buffing action in the counterrecoil buffer) in counterrecoil.

The procedure for checking the level of recoil fluid in the recoil system is similar for all guns with hydraulic recoil systems. The 5"/38 (which we continue to use as an example) differs from others principally in that there are separate vent and filling holes in the recoil system, one on each cylinder. (The conventional arrangement, with a single recoil cylinder, is to have one hole only.) They are closed by hex-head screw plugs, and are labeled VENT PLUG (left cylinder) and FILLING PLUG (right cylinder).

To check the fluid level, position the gun at the elevation prescribed for draining excess fluid, and remove the plugs. If no fluid flows out, depress the gun by a few minutes of arc. If the recoil system has sufficient fluid, some should flow either when the plugs are first removed or when the gun is depressed slightly. If the gun must be depressed appreciably (two to three degrees or more) before flow begins, the recoil system should be replenished.

NOTE: The gunnery officer, or a commissioned officer designated by him, MUST be present during this process.

Counterrecoil Systems

Maintenance operations on counterrecoil systems are normally the GM1's responsibility. However, there is one inspection chore you can do—namely, checking oil level in the differential cylinder.

There's an automatic indicator of the amount of oil in the differential—all you have to do is to look at it. It's the differential piston rod. As you remember from earlier in this chapter, the end of the rod is flush with the cylinder head when the system is fully charged with oil. (See fig. 11–10.) However, as the amount of oil in the differential cylinder becomes smaller, the pressure of the air in the recuperator drives the differential piston farther over toward the oil end of the cylinder, causing the piston rod to protrude. When the rod protrudes two inches or more, it's time to recharge the differential with oil. Never let the rod protrude as much as four inches.

It is important to measure and record the protrusion of the rod in the course of every daily check, and compare it with that of the previous day, even if it is obviously less than two inches. If there is a noticeable difference from day to day, the system has an oil leak that requires investigation.

Checking AIR pressure in the recuperator system is more complicated, and we do not take it up in this course. Replenishing counterrecoil system air or oil, and "running in" the gun by working with the counterrecoil system, are likewise beyond the scope of this course, though you will probably participate in these operations (under the supervision of a qualified Gunner's Mate) if you are assigned to a 5-inch or larger mount.

SUMMARY

In this chapter we have reviewed the theory of operation and the constructional details of typical recoil and counterrecoil systems of naval gun mounts. In the next chapter, we shall take up a type of weapon in which the problem of recoil has been entirely eliminated by using its force to propel the projectile itself. This weapon is, of course, the rocket launcher. We'll also discuss A/S projectors which, though they aren't rocket launchers and do develop recoil forces, are much different from guns.

QUIZ

In each of the following multiple-choice questions, select the one BEST answer.

1. Recoil energy not absorbed by the hydraulic recoil brake
   a. is stored in the counterrecoil system
   b. causes the recoil fluid to heat up
   c. is transmitted to the ship's structure
   d. reduces the maximum instantaneous recoil thrust developed by the burning of the propelling charge
2. The length of recoil of a 5"/38 gun is about
   a. 8 inches
   b. 12 inches
   c. 15 inches
   d. 47 inches
3. Which of the following is NOT one of the differences between the 5"/38 and the 3"/50 recoil systems?
   a. The 3"/50 system uses one cylinder instead of two
   b. 3"/50 systems have throttling rods instead of grooves
   c. In 3"/50 systems the recoil cylinders are standing parts rather than recoiling parts
   d. 3"/50 systems are not equipped with equalizer holes
4. Which of the following components of the 40-mm recoil system is a recoiling rather than a standing part? (Unless you're well acquainted with the construction of this recoil system, you'd better take a quick look at figure 11–4 before answering this one.)
   a. Throttling rod
   b. Throttling bushing
   c. Check valve
   d. Needle valve

5. The thrust of the counterrecoil spring on the 3″/50 mount with Mk 26 or Mk 27 slide, when the gun is in battery, is
   a. zero
   b. 1,500 psi
   c. 3,000 pounds
   d. 6,000 pounds
6. In 40-mm mounts, adjustment of the counterrecoil buffer needle valve regulates
   a. recoil velocity
   b. recoil length
   c. counterrecoil length
   d. rate of fire
7. In 5″/38 mounts, the counterrecoil buffers function
   a. during the end of the counterrecoil stroke
   b. throughout the full counterrecoil stroke
   c. whenever counterrecoil cylinder pressure is too high
   d. whenever rate of counterrecoil movement is too fast
8. The purpose of the differential system in hydropneumatic counterrecoil systems is to
   a. return the gun to battery after recoil
   b. maintain the oil seal under higher pressure than the air
   c. maintain constant air pressure as the gun moves in and out of battery
   d. prevent Diesel action between the oil and air in the recuperator system
9. When the recoil cylinders of a 5″/38 gun are correctly filled:
   a. The differential piston rod is flush with the cylinder head
   b. The cylinders are completely full and can hold no more fluid
   c. The cylinders have an empty space or void
   d. The fluid is under a pressure of 1,550 psi
10. Differential cylinder oil should be replenished when:
   a. The differential piston rod is flush with the cylinder head
   b. The differential piston rod protrudes two inches or more from the cylinder head
   c. The air pressure goes below 1,450 psi
   d. Checking the recoil fluid level indicates that fluid is low

CHAPTER 12

PROJECTORS AND ROCKET LAUNCHERS

INTRODUCTION

Now we take up power-driven projectors and rocket launchers—specifically the Mk 10 and Mk 15 projectors and the Mk 102 and Mk 108 rocket launchers. The Mk 102 is a barrage rocket launcher used on LSMR's; the others are antisubmarine (A/S) "ahead-throwing" weapons.

Scope of this Chapter

In this chapter we'll briefly describe each of these types of mount and its operation, including the principal safety precautions associated with it. We'll not go into detail here about projector charges and rocket ammunition. You should be already acquainted with them in general from the preceding course in this series; perhaps you have handled them in the course of your shipboard duties. In any event, they are discussed in detail in a later course in this series.

The qualifications for advancement with which you must comply to be promoted to GM2 require that you be sufficiently familiar with these rocket launchers and A/S projectors to be able to act as mount captain in a rocket battery or on an A/S projector mount. You are also expected to be thoroughly familiar with safety precautions relating to rocket launchers, A/S projectors, and their ammunition.

The discussion here, because it is limited to but one chapter in a course that must take up many other topics than this, will unavoidably omit a good many details. But it will indicate sources you can go to for further guidance. It is your responsibility to stay up to date on OP's, OD's, and other sources of ordnance information.

We'll begin with the Mk 102 launcher, then take up the A/S weapons.

ROCKET LAUNCHER ASSEMBLY MK 102 MOD 0

The Mk 102 Mod 0 rocket launcher is a barrage weapon designed for installation on Landing Ships Medium, Rockets (LSMR). It is an automatically loaded, remotely controlled twin-tube rocket launching mount which fires 5-inch spin-stabilized barrage rockets at a sustained rate of 30 per minute. In the normal LSMR installation, ten mounts are ranged along either side of the ship (five on each side) on the main deck, from about amidship forward almost to the bow. The rocket battery directors are aft.

The best information source on this launcher is OP 1424.

Structure and Main Components of the Mk 102 Rocket Launcher

We can consider the structure of the Mk 102 rocket launcher as being made up of above-deck components, suspended components, and fixed components.

The main structural above-deck components (fig. 12–1) are a pair of tubular ROCKET GUIDES and a CRADLE, both of which can elevate independently, a CARRIAGE which can rotate in train, and a STAND secured to the deck. The train and elevation drive units are attached to the carriage pedestals.

The suspended components (fig. 12–1) are the twin ammunition hoist tubes and hoist mechanisms, including their power drives, all of which hang from the underside of the carriage base ring. The hoist tubes extend up

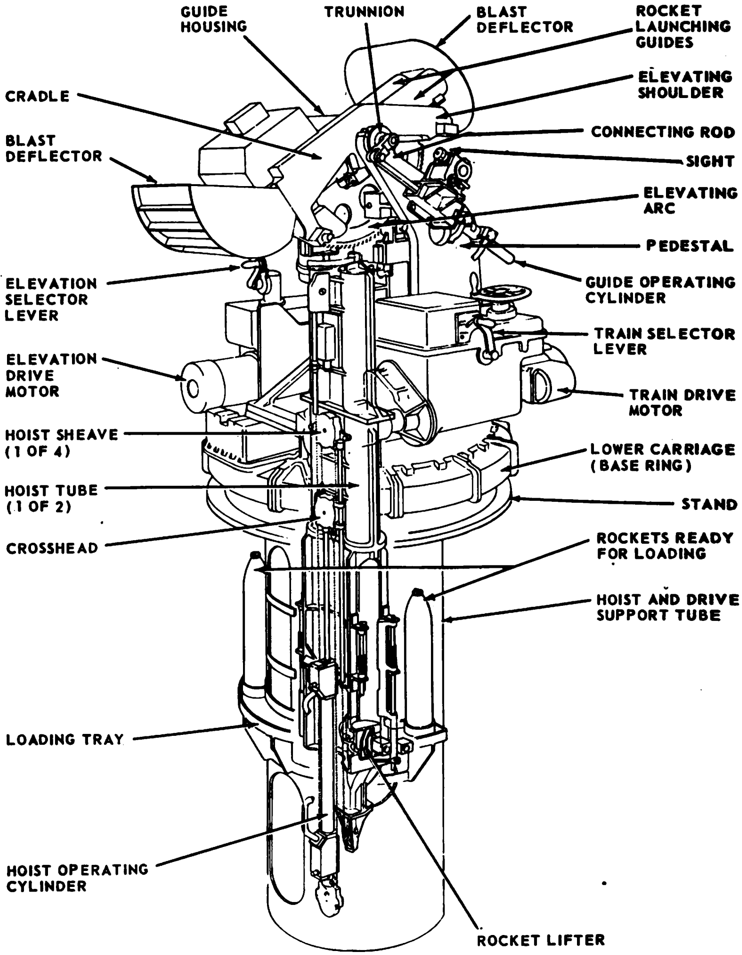


Figure 12–1.—5-inch Rocket Launcher Assembly Mk 102 Mod 0.

through a hole in the center of the carriage, and align with the guide tubes when the latter are in loading position. The hoist units are enclosed in a support tube whose lower end rests in a pivot assembly on the handling room deck. All cable connections between the on-mount units and units on the ship's fixed structure pass through the center of this assembly.

The fixed structure units (not illustrated) include two motor-generator sets, an amplifier unit, power switch, and control unit, all of which are associated with the train and elevation power drives, and a number of electrical units that are part of the firing circuit.

Features of the Mk 102 Rocket Launcher

Before we go into detail concerning the description and operation of the Mk 102 rocket launcher, note the following features of its design:

1. The carriage normally is trained and the cradle elevated and depressed by Mk 4 Amplidyne all-electric power drives very similar to those used on Mk 1 Mod 2 40-mm mounts. Local or manual control is used for synchronizing, exercise, and test.
2. The hoist is lifted and lowered and the guide tubes are elevated and depressed by hydraulic cylinders which are part of an electrohydraulic system. Though they receive their hydraulic fluid from the same pump, the hoist and guide cylinders operate independently. The hoist-operating cylinder through a rope-and-sheave system, raises and lowers a rocket lifter between the handling room and the rocket guides. The guide operating cylinder elevates the guides to vertical (90°) loading position and depresses them until they rest on the elevating shoulder of the cradle (firing position). Guide elevation in firing position depends on cradle elevation, which in turn depends on the elevation order signal from the director as transmitted through the Amplidyne elevation power drive.

3. A system of control interlock switches automatically controls the sequence of operations for hoisting the rockets, positioning the guide tubes, and firing. This system includes safety features for the protection of personnel and equipment. An emergency stop switch on the suspended hoist structure can be operated to stop the power drives and interrupt firing in case of a handling room casualty. A relay breaks the firing circuit if the launcher is out of synchronism in train or elevation or has run into any of its limit stops. A firing stop mechanism interrupts firing when the guide tubes are aimed at some part of the ship's structure.

General Data on the Mk 102 Rocket Launcher

Total weight (lb)	11,000
Guide firing position elevating limits (°)	
Mechanical limit	63
Electrical limit	60
Guide firing position depressing limits (°)	
Mechanical limit	0
Electrical limit	5
Loading position of guide	90
Carriage train limits, from zero (°)	
Left or right, mechanical	180
Left or right, electrical	160
Approximate rate of fire (rd/min)	30
Nominal maximum range (yd)	10,000

Description of the Mk 102 Launcher

Let's look a bit closely at the launcher, beginning with the top and working downward.

Oscillating assembly. (See fig. 12–1.) The main parts of this assembly are the two rocket launcher guides, the cradle, and the sight. The oscillating assembly shifts between two positions—the angle at which the rockets are fired, and loading position. The guide tube operating cylinder swings the guide tubes by a connecting rod between loading position (guides at 90°) and firing position (guides resting on cradle elevating shoulder). There are four guide tube buffers to absorb the shock of the rapid shifts between these positions. At the forward end of the guides is a blast shield, and at the rear of the oscillating assembly is a blast deflector. These protect equipment and personnel from the rocket exhaust. Attached to the guides and cradle are a number of control interlock switches which control firing and guide tube movement.

The cradle's main components are the elevating arc, a gear segment driven by the elevating pinion, and the elevating shoulder, a rectangular cast-steel frame which limits guide tube downward movement.

Carriage. (See fig. 12–1.) The carriage includes or supports all the parts of the mount that move in train. It's a 40-mm carriage Mk 1 Mod 2, modified for the rocket launcher. It supports the power drive units, oscillating assembly, and ammunition hoist. The main structural parts of the carriage are the base ring (lower carriage), and pedestal and trunnion support (upper carriage). The power drive units on the carriage include the gearing and power motors for positioning the mount in train and elevation. The elevating pinion driven by the elevating gear engages the elevating arc; the training pinion engages the training circle in the stand.

The carriage also contains the firing stop system and the cooling system. The firing stop, mounted on the forward part of the pedestal, is similar in principle to the 5-inch gun mount type that you are already acquainted with. It consists of a disc rotated by mount train with a cam follower moved radially by mount elevation; the safe firing zone is the cut-out portion of the cam's surface. The cam follower opens and closes the firing circuit. The cooling system (not illustrated) is an emergency arrangement consisting of a pipeline up the right side of the mount terminating in a perforated pipe across the top of the cradle. It's used in case of apparent or actual misfire, when it's connected by hose to the fire main.

Stand. This, again, is a 40-mm mount unit—specifically, the one used for the Mk 1 twin 40-mm mount—so we needn't go into it any further.

Elevation and train power drives. These are Mk 4 Mod 3 all-electric Amplidyne units of the type used on Mk 1 Mod 2 twin 40-mm mounts. In automatic control, each power drive system receives, from the director, elevation or train orders in the form of double-speed synchro signals. In the mount receiver-regulator these are converted to a-c voltage signals and rectified. The signals control the output of Amplidyne generators that drive d-c power motors on the mount. The motors respectively drive the cradle through gearing to the elevation pinion for movement in elevation, and the carriage through gearing to the training pinion for movement in train. (Fig. 12–2 is a functional schematic of the train drive; the elevation drive is similar in general.) For local power control the mount is still driven through the amplifiers, motors, and gearing, but the electrical signals to the amplifiers are furnished by small tachometer generators driven by the elevation and train handwheels operated by the crew. In manual control the handwheels directly drive the gearing

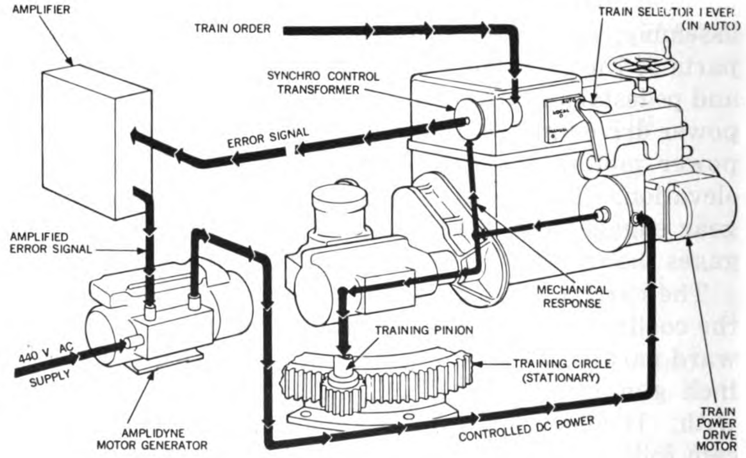


Figure 12–2.—5-inch Rocket Launcher Assembly Mk 102 Mod 0. Train control system (functional schematic).

to the elevating and training pinions respectively, and the electrical units are not involved.

The selectors for choosing the type of control to be used are located on the train and elevation drive units on the mount. The gearing, drive motors, synchros, and tachometer generators are also located on the mount; the other components, including the Amplidyne motor-generator sets, their control and overload units, and the amplifiers are located in the handling room off the mount. Magnetic brakes on the elevation and train drive motors automatically function to stop the mount if there is an overload or power failure.

Ammunition hoist. (See fig. 12–1.) This is a hydraulically operated lift designed to raise two rockets at a time from the handling room level into the rocket guide tubes. Its main structural components are a hoist and drive support tube within which are two hoist tubes. The hoist is suspended from the base ring, but the two hoist tubes extend from below the loading tray of the support tube up through the stand so that they meet the rocket guide tubes when the latter are in loading position. Hinged spring-loaded covers over the tubes close them off when the rocket guide tubes are in firing position; in loading position the covers are cammed open.

The rocket lifter (not visible in fig. 2–1) is a Y-shaped steel casting which moves up and down on a guide between the hoist tubes. The arms of the Y protrude into the tubes and terminate in small platforms which support the rockets being hoisted. The lifter is secured through two ropes and a system of sheaves to the crosshead on the hoist operating cylinder's piston rod. The rope-and-sheave arrangement multiplies piston movement by two, so that the piston stroke is half that of the lifter.

The other parts of the hoist hydraulic system include a motor-driven vane pump, supply tank accumulator, oil filters, interconnecting piping, and valves. The flow control valves, two check valves and a solenoid operated hoist cylinder control valve regulate fluid flow to and from the hoist operating cylinder. The guide operating cylinder also operates from the hydraulic system; fluid flow into and out of this cylinder is governed by two adjustable control and check valves, and a solenoid-operated guide control valve. The system operating pressure is 1,000 psi, and its oil capacity is 22 gallons. The solenoid-operated valves are tied electrically into the control interlock circuit, which starts and interlocks the hydraulic cylinders that operate the rocket lifter and the rocket guides.

Firing components and circuits. These don't constitute an assembly in the same sense as those we've described above. But understanding their function is essential to an understanding of the whole. The main components we're concerned with here are the Mk 20 firing panel, the emergency stop switch, the firing stop mechanism, the Mk 9 relay, the firing transformer, the amplifier, the intervalometer, the firing interlock switch, and the firing contacts. Figure 12–3 shows schematically how they fit into the firing process. The firing panel, intervalometer, and firing transformer are physically located on the handling room bulkhead, the emergency stop switch and Mk 9 relay

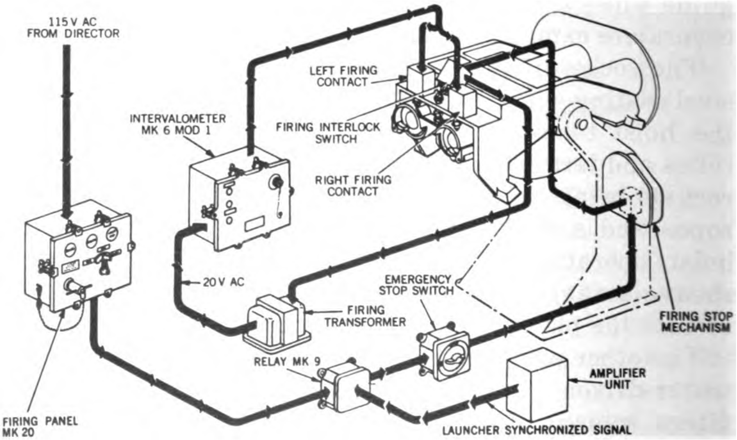


Figure 12—3.—5-inch Rocket Launcher Assembly Mk 102 Mod 0. Firing control system (functional schematic).

are on the hoist structure in the handling room, the firing stop mechanism is on the carriage, and the firing interlock and contacts are on the elevating shoulder.

We don't have to go into detail about the firing stop mechanism, which you know something about already. The firing contacts and interlock are simple; the contacts touch the rockets in the guides when the guides are in firing position, and the interlock switch closes as the guides approach the elevating shoulder. But let's consider briefly the other above-mentioned components of the circuit.

The firing panel has a safety plug, a three-position selector switch, and three pilot lights. The plug is removed to interrupt the firing circuit. The selector can be set to DIRECTOR, LOCAL, or OFF. The red pilot light, marked READY, indicates that the intervalometer motor is energized and the selector is set to either LOCAL or DIRECTOR; the green light, marked DIRECTOR, indicates that the firing circuit from the director is energized; and the amber light, marked CEASE FIRE, along with a cease fire horn, shows that the cease fire signal has been given.

A pair of rockets fired both at once from the Mk 102 launcher would be likely to crash into each other in flight, or at least their flight would be erratic. So, the launcher fires its pair of rockets one AFTER the other on one firing signal, rather than both at once. The delay introduced is 0.66 second, and the timing device that takes care of it is the INTERVALOMETER. Its main functioning elements are two microswitches (one for the firing circuit to each rocket guide tube firing contact) and a cam drum rotated by a synchronous motor at 15 rpm. Screws in the drum cam the switches every 0.66 second while the motor is running. There are three indicator lamps in the left side of the intervalometer cover. The upper one, marked M, indicates that motor power is on, and the other two, numbered 1 and 2, indicate when power is supplied to the firing contact circuits. An access hole in the right side of the cover, normally protected by a cap, makes it possible to start the motor by hand if necessary.

The intervalometer receives the 20-v a-c firing current from the secondary of the firing transformer, and feeds it direct to the firing contacts on the rocket guide tubes. But, as you can see in figure 12–3, the 115-v a-c firing signal from the director goes through several other circuit elements before it gets to the firing transformer's secondary. It first goes through the firing panel already described. Next, it goes to the contacts of the Mk 9 relay. The relay's coil receives 115-v a-c from other relays in the train drive amplifier; this current is interrupted when the launcher is not synchronized in train. Since the relay contacts are open when the relay coil is not energized, the 115-v circuit to the firing transformer primary cannot be closed unless the launcher is synchronized with train order.

The 115-v circuit to the firing transformer primary also passes through the emergency stop switch on the hoist at the handling room level. This switch controls two circuits—the 115-v firing circuit shown in figure 12–3 and the regulator circuit of the train power drive. Thus the handling room crew can stall the train drive and stop the firing if a casualty makes such emergency action necessary.

Lastly, this circuit is completed through the firing stop mechanism on the front of the launcher carriage. You're already familiar with the principle and purpose of this device.

Functioning Cycle of the Mk 102 Launcher

Now let's follow the functioning cycle of the Mk 102 launcher as it fires a pair of rounds. Except for loading the rocket lifter down in the handling room, the cycle is completely automatic. In normal automatic fire, each rocket guide tube fires a rocket every 42 seconds.

We begin with the launcher in the condition shown in figure 12–1—namely, with the rocket lifter at the bottom of its stroke, and the hoist tubes empty. Under these con-

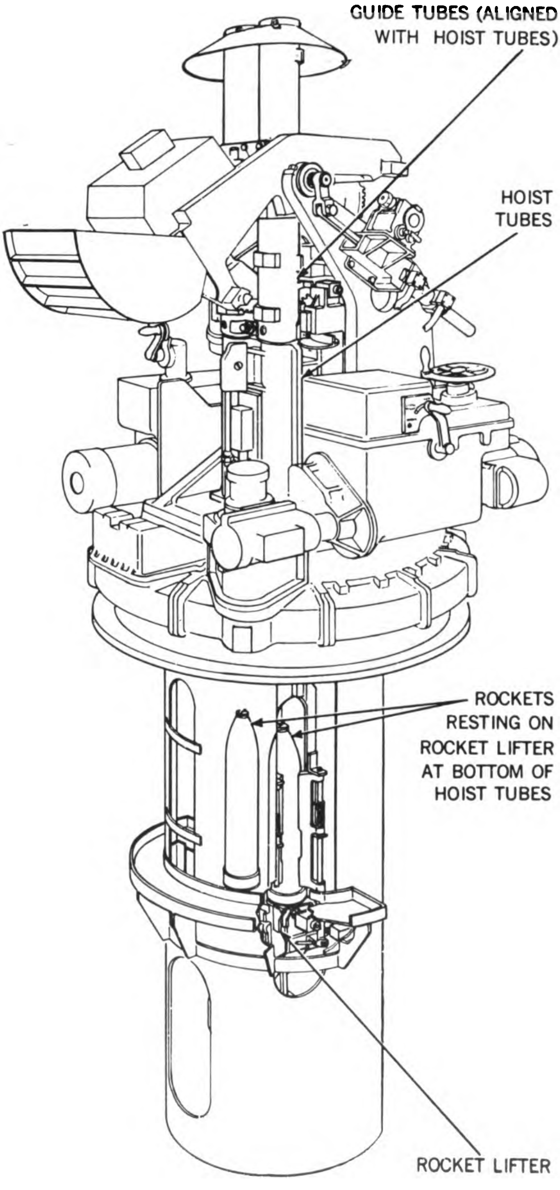

GUIDE TUBES (ALIGNED WITH HOIST TUBES)
HOIST TUBES
ROCKETS RESTING ON ROCKET LIFTER AT BOTTOM OF HOIST TUBES
ROCKET LIFTER

Figure 12–4.—5-inch Rocket Launcher Assembly Mk 102 Mod 0. Hoist loaded; guide tubes at loading position.

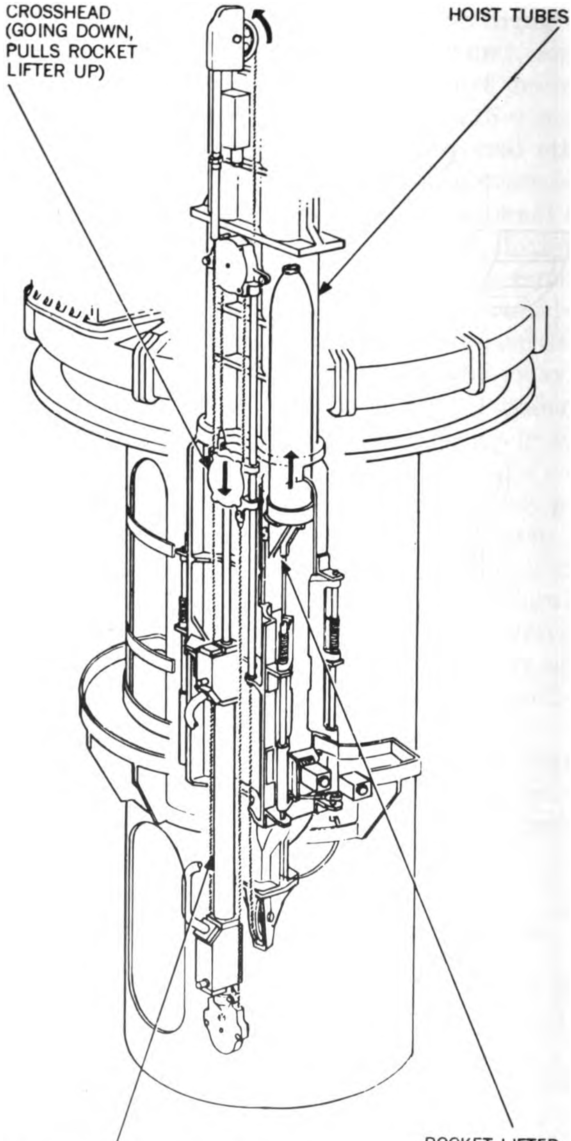


Figure 12–5.—5-inch Rocket Launcher Assembly Mk 102 Mod 0. Hoisting action.

ditions, the lower hoist interlock switches are open and the hoisting cycle cannot begin.

HOIST LOADING. (See fig. 12–4.) The handling room crew pushes two rounds through the shutters at the hoist lower end onto the rocket lifter. This actuates interlock switches on the shutters and at the end of the loading tray. When the guide tubes move into loading position, the hoisting circuit is completed.

HOISTING ACTION. (See fig. 12–5.) Now a control valve is opened by a solenoid in the hoisting circuit. It ports hydraulic fluid into the top of the hoist-operating cylinder; the piston and crosshead move down, causing the rocket lifter, through the rope-and-sheave action, to move up.

GUIDE LOADING AND LATCHING. (See fig. 12–6.) The

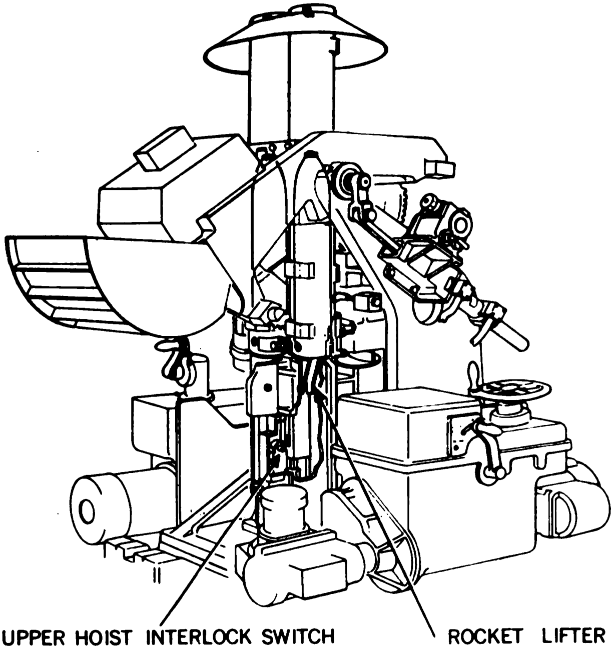


Figure 12–6.—5-inch Rocket Launcher Assembly Mk 102 Mod 0. Loading the guide tubes.

rocket lifter, as it approaches the top of the hoist tubes, opens the upper hoist interlock switch. This prevents the guides from leaving the loading position too soon. The rockets pass into the guide tubes, pushing the rocket latches aside. When the rockets are completely inside the tubes, the latches snap back to hold the rockets in the tubes.

HOIST LOWERING ACTION. (See fig. 12–7.) Loading and latching of the rockets in the guide tubes closes the control interlock system circuit, which initiates the downward stroke of the lifter. In hoist lowering action, a

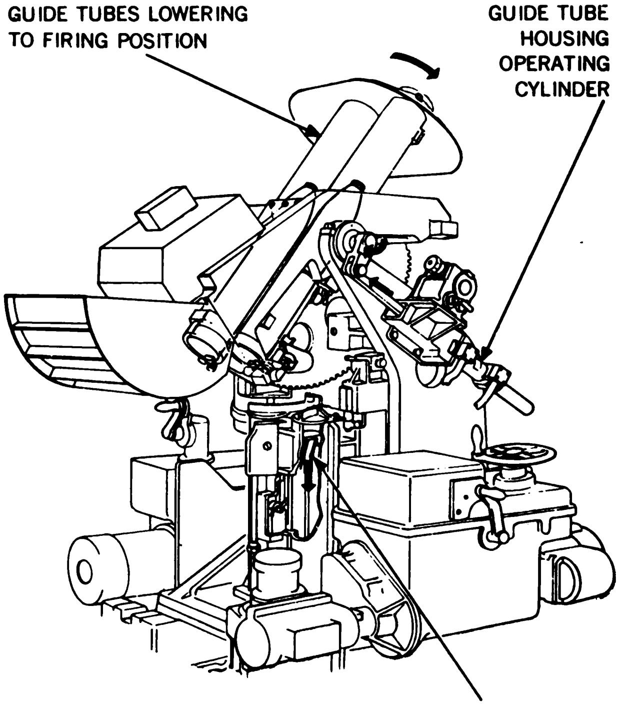

GUIDE TUBES LOWERING TO FIRING POSITION
GUIDE TUBE HOUSING OPERATING CYLINDER
ROCKET LIFTER GOING DOWN

Figure 12–7.—5-inch Rocket Launcher Assembly Mk 102 Mod 0, Lowering the guide tubes.

solenoid-operated control valve feeds hydraulic fluid to both ends of the hoist-operating cylinder. Since the piston rod is on the upper side of the hoist-operating piston, the total area presented to fluid pressure is smaller than on the lower side. By the differential-area principle that is by now familiar to you, the upward thrust on the piston's bottom therefore exceeds the downward thrust on its top, and the piston and crosshead move up, hauling the rocket lifter down.

GUIDES MOVE TO FIRE POSITION. (See fig. 12–7.) After moving downward 4 inches, the hoist lifter releases the normally closed upper hoist interlock switch. This completes the guide tube lowering circuit, and hydraulic fluid under pressure is ported by a solenoid-operated control valve to the lower end of the guide tube operating cylinder, which depresses the guide tubes until they are resting on the elevating shoulder (which is at firing elevation).

FIRING. (See fig. 12–8.) When the rocket guides are aligned with the elevating shoulder, an adjusting bolt at the after end of the guides depresses the plunger of the firing interlock switch, closing it. At the same time the firing contacts on the rear of the elevating shoulder touch the contact bands on the rockets. If (as explained in the previous paragraphs on the firing circuit) all the other units in the circuit are set to fire, the firing current sets the rockets off.

Meanwhile, the rocket lifter has reached the bottom of its stroke, and the hoist can be reloaded. As soon as both rockets being fired are clear of the guide tube bores, bore-clear switches (one in each tube) close a circuit which through a solenoid causes a control valve to port hydraulic fluid under pressure to the upper end of the guide operating cylinder. The cylinder elevates the guide to loading position, and the cycle repeats.

Because the Mk 102 has no mechanical hoist feed, its maximum rate of fire depends entirely on the efficiency of its loading crew.

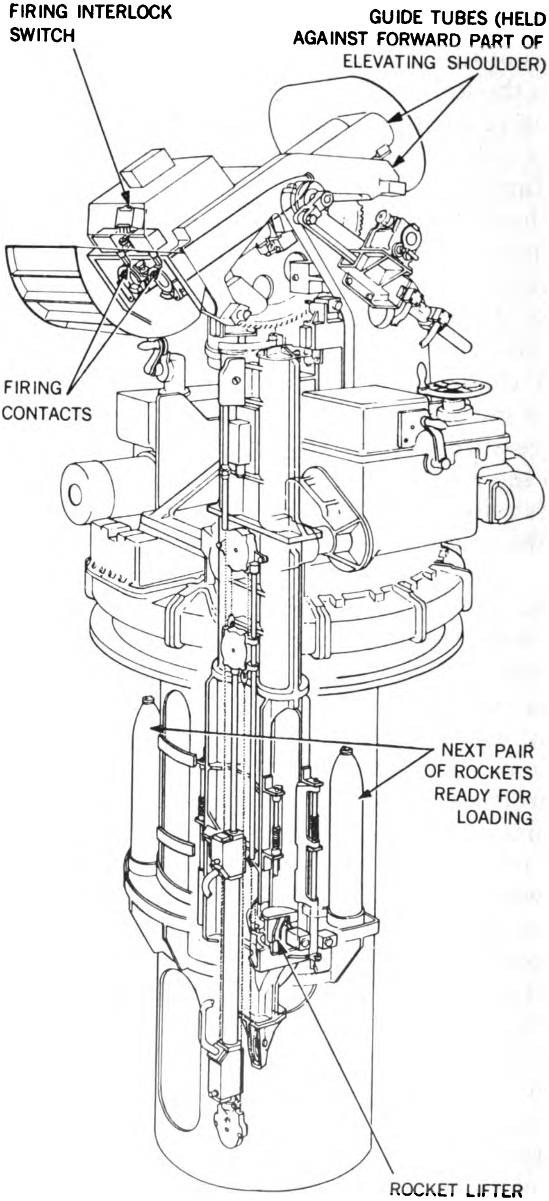

FIRING INTERLOCK SWITCH
GUIDE TUBES (HELD AGAINST FORWARD PART OF ELEVATING SHOULDER)
FIRING CONTACTS
NEXT PAIR OF ROCKETS READY FOR LOADING
ROCKET LIFTER

Figure 12–8.—5-inch Rocket Launcher Mk 102 Mod 0. Guide tubes in firing position; lifter at bottom of hoist.

Crew Stations and Duties on Mk 102 Rocket Launcher

The normal crew required on this launcher comprises 11 or 12 men (depending on mount location). Figure 12–9 shows all of them but one—the launcher control man, who is stationed above deck. In the handling room are two first loaders, two second loaders, two rocket handlers, and the petty officer in charge. Here are their duties:

LAUNCHER CONTROL MAN. When the order CONDITION ROCKET is given, all personnel forward of the ship's island

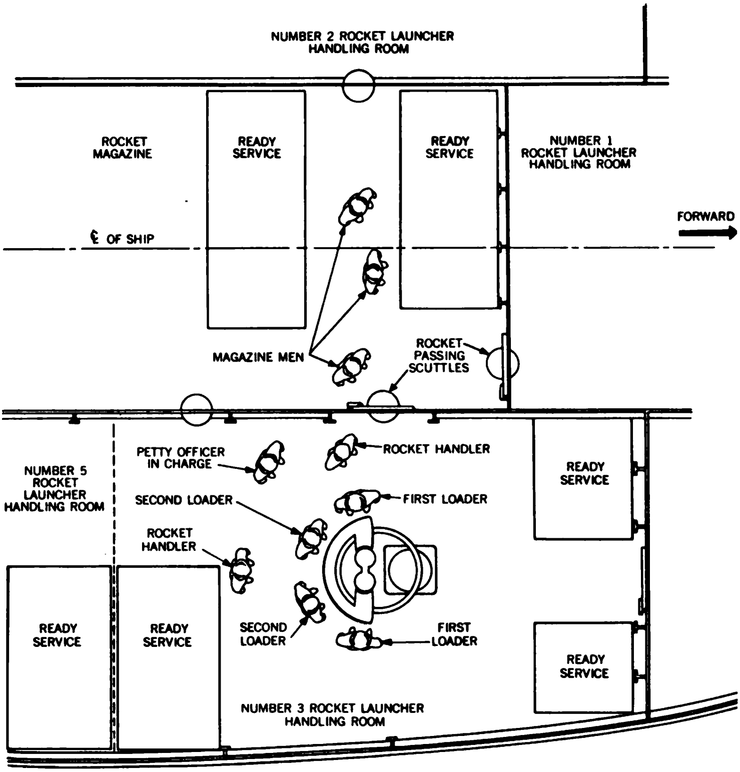


Figure 12–9.—5-inch Rocket Launcher Assembly Mk 102 Mod 0. Crew stations (rocket handling room and magazine).

are ordered below deck except the launcher control man. He casts loose the launcher in elevation and train, energizes the elevation and train power drives, and positions the power drive selector levers to AUTO. Then, at the blast of a siren, he goes below.

FIRST LOADER. A first loader is stationed at each loading opening of the ammunition hoist. He places the rockets on the rocket lifter.

SECOND LOADER. A second loader assists each first loader and holds rockets on the loading tray before they are loaded into the hoist.

ROCKET HANDLER. The rocket handlers lift rockets from the cases in the handling room, or pass them from the ammunition scuttles of the magazine to the loading tray.

PETTY OFFICER IN CHARGE. The petty officer in charge supervises loading of rockets into the ammunition hoist. starts up the hoist drive, and acts as talker for the group.

MAGAZINE MEN. The magazine men assemble the rocket body, motor, and fuze before the ammunition leaves the magazine.

Maintenance of the Mk 102 Rocket Launcher

In this chapter it is not possible, either here or for the other equipments described, to give fully detailed maintenance instructions. For these you must go to the OP. But we can summarize the high spots.

The main operations in routine maintenance are inspection, exercise, cleaning, lubrication, and firing circuit checking. Less frequently you must paint, adjust, disassemble for thorough cleaning and repacking, and perform other more time-consuming operations. The frequency of the operations is prescribed in check-off lists; the details of lubrication are given in lubrication charts.

In the Mk 102 rocket launcher all moving parts such as latches and cams should be checked to see that they function properly and don't bind or jam in operation. Periodically examine electric cables on the guides and cradle to ensure that there has been no deterioration because of blast heat. Check electrical contacts and clean if necessary. Be sure to replace inspection covers (such as those on the firing stop mechanism, elevating gear worm drive, and the like) after inspection, and every time a cover is removed and replaced check the gasket to see that it is in satisfactory condition. Check all oil seals for leakage and replace if necessary; when replacing, make sure the oil seal faces in the proper direction. When exercising the mount, operate it in elevation and train both in power and manually through the extremes of its movement; see that the limit stops function properly.

Since frequency of lubrication of power drives depends on actual hours of operation, this should be logged. After every lubrication, exercise the equipment. In the ammunition hoist, check the accumulator before operating the mount; the pressure should be 600 psi with the oil chamber vented. Check flow control valve settings against the log, and check fluid level in the tank. The OP also prescribes a procedure for exercising the hoist with dummy ammunition.

Mk 102 Rocket Launcher Misfire Procedure

You have a misfire if a launcher ceases to operate during firing, with the hoist tubes loaded and firing power available. The firing circuit should remain energized, because misfire may be due to poor firing contact or functioning of the firing stop mechanism. Vibration, or moving the rocket guides, may fire the rockets. Rockets already loaded into the hoist tubes at the time of misfire must remain in the tubes until the assembly resumes automatic firing, or until the rockets can be safely removed. To correct the trouble, to prevent cook-off, and to resume normal automatic fire quickly, when a misfire occurs, proceed as follows:

Misfire procedure before "cease fire."

1. Immediately connect the emergency water hose in the ammunition handling room to the cooling system. Open the main valve, and allow water to flow over the cradle until at least one minute after steaming has stopped.
2. Do not attempt to remove the rockets from the guides until CEASE FIRE is sounded for all launchers, or until all launchers, whose lines of fire or exhaust are in line with the misfired launcher, have ceased firing.

   CAUTION: Prior to the removal of the rockets from the guide tubes, keep the oil pump motor in operation so the guides will stay in the firing position.

Misfire procedure after "cease fire."

1. Remove safety plug from firing panel. After 10 minutes, start to remove rockets from guide tubes.
2. Stop the oil pump motor. Open the hand valve to vent the accumulator. The rocket guides will fall away from the elevating shoulder and clear of the blast deflector. But keep the loaded tubes from aligning with the hoist tubes.
3. Stop the elevation and train power drives, and set the selectors at MANUAL.
4. If necessary, depress the elevating shoulder to make room at the rear of the guides for rocket removal. Hold the guides away from the hoist tubes, manually retract the latches, and remove the rockets from the rear of the tube.
5. If bomb disposal personnel are not available, cast misfired rounds overboard in deep water without delay.

General Safety Precautions with the Mk 102 Launcher

Safety is always a primary consideration in dealing with ordnance equipment—particularly if the equipment is concerned with live ammunition, as any rocket launcher is, big or small. With a complex weapon like the Mk 102 launcher there's quite a lot to safety both in operation and in maintenance of the equipment. We'll give here the more important safety precautions associated with rocket launcher operation. For further details on safety precautions in operation, and for safety precautions as they apply to maintenance and testing, see OP 1424.

1. NEVER stand directly behind loaded guide tubes.
2. NEVER attempt to remove live rockets from the forward end of the guide tubes.
3. EVERYBODY ALWAYS must keep clear of the exhaust path of the rockets.
4. NO ONE may approach closer than 10 feet of any rocket launcher that is firing or is about to be fired. When beyond this 10-foot minimum distance, everyone must keep clear of the line of fire of any other launcher that is firing or is about to be fired.
5. Any assembly whose guides do NOT return to the loading position after "cease fire" should be treated as loaded, and misfire procedure should be observed.
6. If the firing stop mechanism fails to operate, do NOT attempt to fire the rocket launcher. Serious damage to ship and personnel may result.
7. Before starting the mount, the operator must take his proper position so that he will be able to control it. Also, he must be sure the securing pin and securing bar have been released before he attempts to start the mount.
8. The handwheels must be at rest before the START button is pressed.
9. Do NOT unload any rocket already in the hoist until the oil pressure pump motor has been stopped and the accumulator has been vented by opening the hand valve.
10. Don't load rockets into the hoist until the accumulator pressure has built up to full value, as indicated by the tripping of the unloading valve.

11. **Never** stow extra rockets loosely on the loading tray around the hoist and drive support tube.
12. When exercising the assembly with dummy rockets, do not attempt to remove the rockets from the front of the guide tubes while the oil pressure pump motor is operating or there is pressure in the accumulator. The guide tubes will start to move to their hoist position as soon as the base of the rocket clears the bore clear interlock, and the operator can be seriously hurt.
13. Keep fingers clear of the rocket lifter in the hoist when depressing the switch actuator platforms.

12.75-INCH ROCKET LAUNCHER MK 108

The 12.75-inch Rocket Launcher Mk 108, formerly known as "Weapon Able," is in some respects similar to the Mk 102 you just read about, but the differences are considerable. The Mk 108 is intended as an A/S weapon rather than a barrage weapon, it fires one rocket at a time rather than two, and it is equipped with an automatically operating 22-round magazine which feeds rockets into the launcher even if the handling room is not manned. But it does have some points of similarity—in operation, the rocket guide oscillates between vertical loading position and firing elevation, the launcher operation is entirely automatic (except for loading ammunition into the lower hoist), and, except for the magazine, the general cycle of functioning is similar.

The ammunition fired by the Mk 108 is designated as the 12.75-inch Rocket Mk 1 Mod 0 (ASP), and is a fin-stabilized rocket with a 12.75-inch diameter head and a 5.75-inch diameter motor. The head is armed mechanically by a vane on its forward end, and the hoisting charge is detonated magnetically by the steel hull of its target. We can't go into further detail on the ammunition here, since it's beyond the scope of this course.

General Data on the Mk 108 Mod 3 Rocket Launcher

Total weight (lb)	43,600
Guide firing position limits (°)	
Elevation	60
Depression	10
Guide position limits for loading and unloading (°)	
Loading	90
Emergency unloading	–10
Train limits (°)	
Left or right from stowed position	150
Rate of fire (rd/min)	12
Magazine capacity (rds)	22
Range (yd)	
Maximum	800
Minimum	400

Main Components of the Mk 108 Rocket Launcher

The main components of a complete Mk 108 launcher assembly (fig. 12–10) are the rocket launcher mount, the ready-service magazine unit, the rocket hoist unit, the control station equipment, and the lower rocket hoist unit. All of these are BuOrd equipment except the lower hoist, which is a BuShips assembly. All of these components are described in full detail in OP 1754, supplemented by BuShips reference handbooks 378–0111 and 378–0123, which deal respectively with the lower hoist units of Bethlehem Steel and Wheeler design.

Let's first look at the rocket launcher mount. Its principal assemblies are the guide, the carriage, the stand, the shield, and the electrohydraulic train and elevation power drives.

Guide. The guide is a 14-foot steel tube open at breech and muzzle, and pivoted in trunnion bearings of the carriage. It is elevated and depressed by an elevating arc and pinion driven by the elevation power drive. It houses the rocket guide rails, rocket firing mechanism, rocket retaining latch, and guide-loaded signal indicating mechanism. The rocket guide tube oscillates in elevation between loading position (90° elevation) and firing position

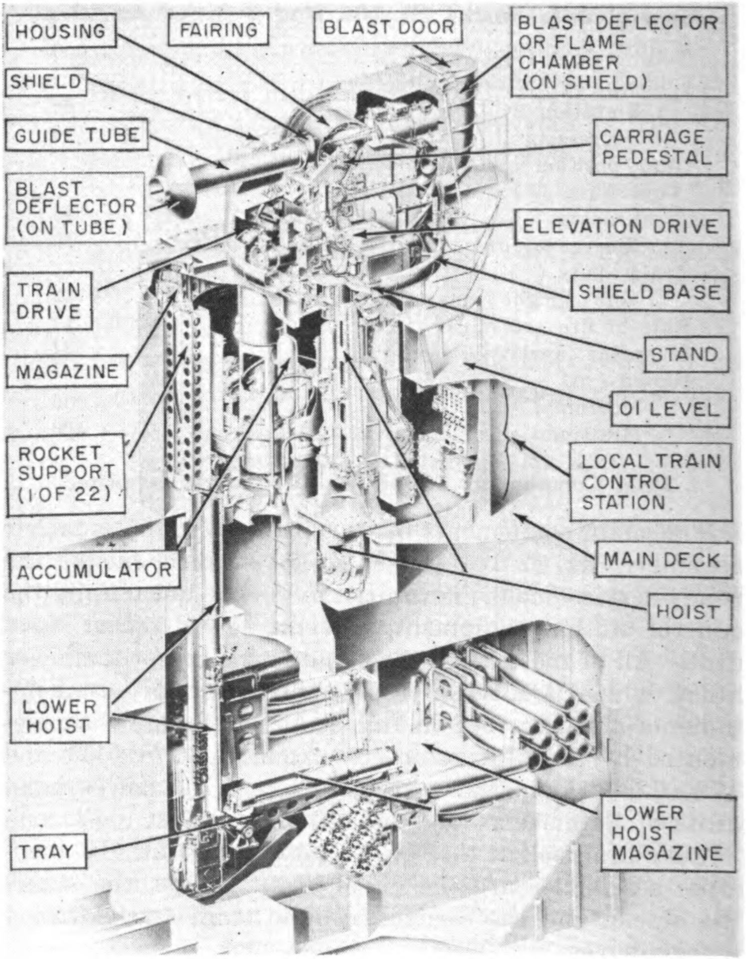


Figure 12–10.—12.75-inch Rocket Launcher Mk 108. General arrangement.

(as ordered by the director in Underwater Battery Plot). In loading position the guide is aligned with the rocket passing hatch; in firing position the tube's after end points into the blast deflector—a power-ventilated flame chamber lined with heat-resistant material which receives the rocket blast and deflects it upward.

Carriage. This is a base-ring type mounting that supports the rotating assembly in the stand. It includes the base ring, carriage pedestal, circular shield base, elevating gear, and training gear. The base ring, a circular weldment that fits within the stand, is supported in three large roller bearings of the stand. The carriage pedestal is fitted at the top with two sleeve bearings in which the guide trunnions fit, and mounts parts of the elevating gear, two guide buffers, a guide latch, the flame walls for the center chamber of the shield, and hydraulic buffer elevation limit stops. The shield base supports the shield, the circular cover that encloses the training circle, and other parts of the training gear.

Other important components in the carriage are a door over the rocket passing latch, and a cable drum device that leads electric supply and communications cables into the rotating assembly and permits full training movement. Other parts of the cable rigging are a cable well and an arrangement of sheaves that are part of the rocket hoist. The hatch door is a heavy pivoted steel plate that slides horizontally over the hatch. It is cammed to open the hatch when the guide is at loading position, and is cammed back to close the hatch when the guide moves toward firing position.

Stand. The rocket launcher stand includes a circular deck mounting unit, carriage roller path bearings to hold the base ring, circular rack (training circle), train stops, and the cable support shroud (which houses the cable rigging). Except for the shroud, all the parts are the same as or modifications of the like parts of 40-mm Stand Mk 1 Mod 0.

Shield. The shield is a combination weather enclosure and blast deflector. It includes, in addition to the main structure illustrated in figure 12–10, fire walls for the guide compartment, a guide port seal device, ventilating fans, heaters, and a sprinkling pipe system. Within the shield, on either side of the flame chamber, are two machinery chambers. The elevating gear and electrohydraulic power drive are on the left, and the training gear and power drive are on the right.

Elevation and train power drives. These are modifications of the electrohydraulic drives originally designed for 40-mm Mount Mk 2 mods. Each consists of an electric motor driven main pump, replenishing pump, hydraulic motor, and control system. The latter consists of a synchro-type signal receiver, electronic amplifier, stroke motor, and stroke control mechanism. This arrangement causes a booster piston to regulate the tilt and hence the output of the Vickers-type main pump, in accordance with the signal from the director. Automatic limit stops decelerate and stop the driven unit at fixed train or elevation limits. The elevation drive also has a hydraulic-operated guide latch that automatically holds the guide at loading position until it is loaded. Now let's look at the other parts of the installation—the ammunition supply components.

Magazine. The ready-service magazine is a large drum-shaped weldment on a roller bearing stand, power driven to turn about its vertical axis. The 22 rocket support ways on the drum successively align beneath the hatch and register with a lifter of the rocket hoist. Within the drum, on a fixed platform of the magazine stand, is the power unit (rocket supply power drive) that rotates the magazine and supplies power to the upper and lower rocket hoists.

Rocket hoist (upper). This is a chain mechanism similar to a bag gun rammer chain. It retracts into a vertically mounted J-shaped track. A chain sprocket at its lower end is turned by the stroking action of a hydraulic cylinder driven by the rocket supply power drive. When the chain extends, a lifter on its end ascends through a rocket support space of the magazine, through the hatch in the carriage, and into the breech end of the vertically positioned guide. The hoist assembly includes at the top of the chain housing a cable well arrangement that guides and stows the slack of the electric cables suspended from the carriage.

Rocket supply power drive. The drive equipment that supplies hydraulic power to the magazine, and upper and lower rocket hoists, consists of an electric motor driven pump, supply tank, accumulator, a pipe system that extends to the driven units of the magazine, hoist and lower hoist, and a system of electric and hydraulic control devices. These units are assembled within the magazine, and are mounted on the magazine stand. They are accessible through a hatch in the stand from the deck below the magazine room.

Lower rocket hoist. The installation for serving rockets to the ready-service magazine includes an overhead trolley transfer rig, a hoist loading tray, both located in the ship's magazine, and a lower rocket hoist. The latter is a hydraulic ram-type mechanism of either one of two designs. These are described in the BuShips publications referred to earlier in this section.

Firing circuit. The firing circuit in general resembles that for the Mk 102 mount, described above, except that it is somewhat simpler. There is no firing stop mechanism; the rocket guide is high in the superstructure, and limit stops prevent training in dangerous areas. Since only one rocket fires at a time, no intervalometer is needed. For further details on the firing circuit, see OP 1754.

Mk 108 rocket launchers come in three mods. Mods 1 and 2 differ in the kind of accumulator used in the rocket supply hydraulic power drive; Mod 3 is like Mod 2 except that some of its structural parts are of aluminum instead of steel.

Mk 108 Rocket Launcher Controls and Crew Stations

The Mk 108 rocket launcher has four local control and one remote control stations, as follows (see also fig. 12–11):

Director control station. This is the remote rocket

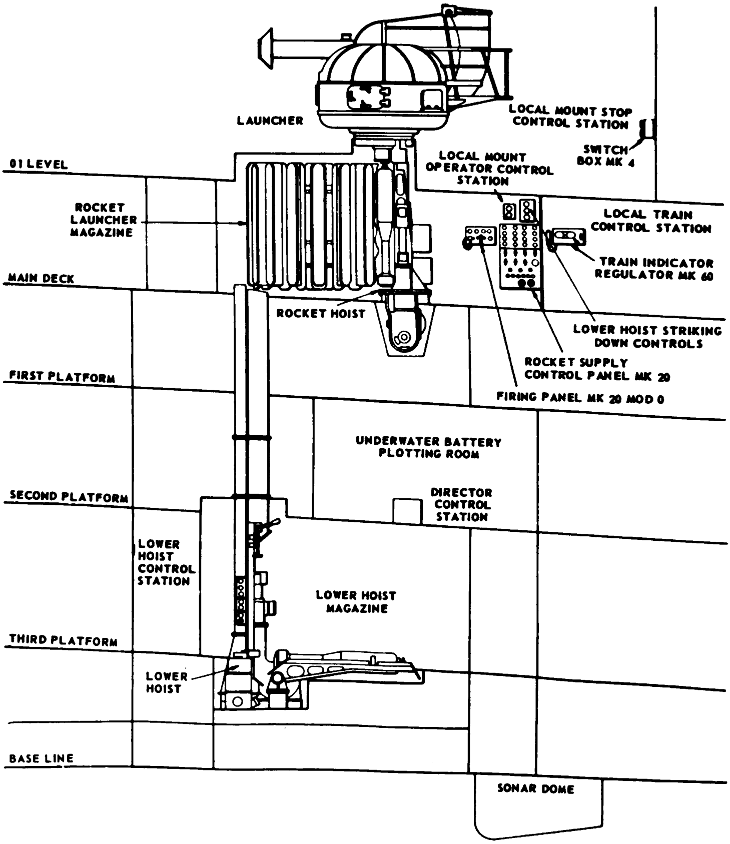

LAUNCHER
LOCAL MOUNT STOP CONTROL STATION
SWITCH BOX MK 4
01 LEVEL
LOCAL MOUNT OPERATOR CONTROL STATION
ROCKET LAUNCHER MAGAZINE
LOCAL TRAIN CONTROL STATION
TRAIN INDICATOR REGULATOR MK 60
MAIN DECK
ROCKET HOIST
LOWER HOIST STRIKING DOWN CONTROLS
ROCKET SUPPLY CONTROL PANEL MK 20
FIRST PLATFORM
FIRING PANEL MK 20 MOD 0
UNDERWATER BATTERY PLOTTING ROOM
SECOND PLATFORM
DIRECTOR CONTROL STATION
LOWER HOIST CONTROL STATION
LOWER HOIST MAGAZINE
THIRD PLATFORM
LOWER HOIST
BASE LINE
SONAR DOME

Figure 12–11.—12.75-inch Rocket Launcher Mk 108. Control stations.

launching control for automatic firing operation. It is located in Underwater Battery Plot.

Local mount operator's control station. This is the below-deck rocket launcher central control for local starting, stopping, and standby control of mount operations, located in the rocket launcher magazine level near the magazine and hoist.

Local train control station is the below-deck follow-the-pointer control for synchronizing carriage train

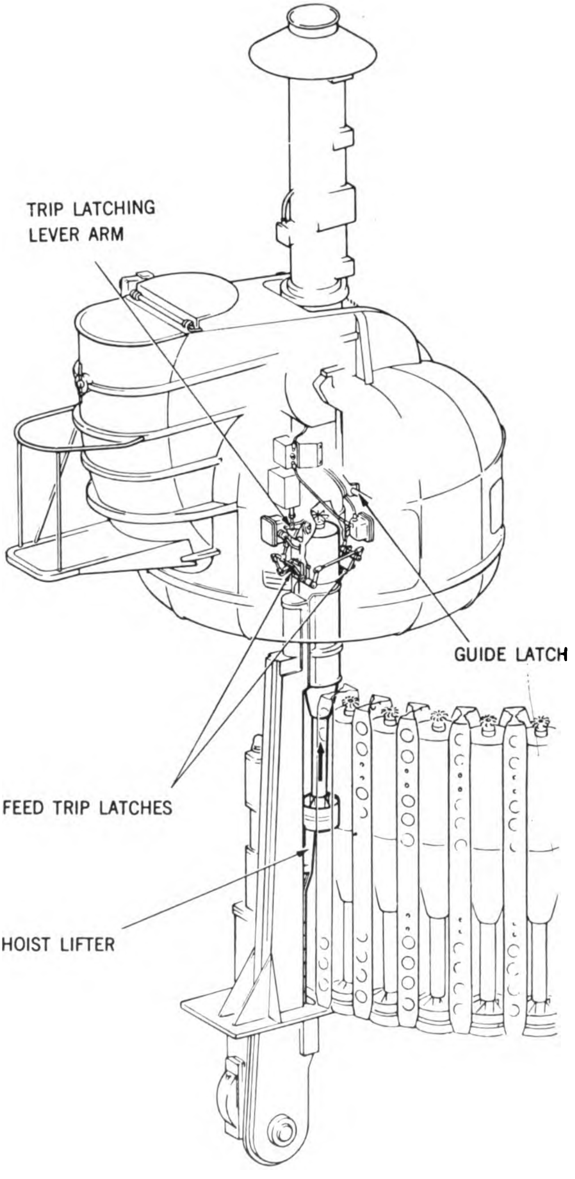


Figure 12–12.—12.75-inch Rocket Launcher Mk 108. Guide loading.

position with director train orders. It's next to the local mount operator control station.

Local mount stop control station is the emplacement deck safety control used to stop mount operation in an emergency.

Lower rocket hoist control station. This, the local hoist operating control, is located at the foot of the lower hoist.

Functioning Cycle of the Mk 108 Rocket Launcher

There are two principal sets of operations in the normal functioning of the Mk 108 rocket launcher. The firing cycle is concerned with moving the rockets in sequence from the drum magazine (ready-service ring) to the guide and firing them; loading is concerned with moving rockets from the lower magazine to the ring.

Firing cycle. This starts with the guide empty and latched in vertical (loading position), the drum magazine fully loaded (22 rounds), and a rocket indexed over the rocket hoist lifter. When the proper interlock is energized, the rocket hoist lifter hoists a rocket up into the guide (fig. 12–12), then moves down again. Two feed trip latches in the breech end of the guide tube support the rocket, and a trip latching lever arm keeps it from drifting toward the muzzle.

As soon as the downward-moving hoist lifter has cleared the guide tube, the tube is unlatched from the carriage, the power drive is switched to the remote director, and the guide depresses to synchronize with the elevation order signal. (See fig. 12–13). When the hoist lifter is all the way down, the ready-service ring latch releases the ring, which revolves far enough to index the next rocket with the hoist, and latches again.

As soon as the guide synchronizes with firing elevation order, the firing circuit is completed through the contacts in the guide tube breech to the squib in the rocket motor, and the rocket fires. (See fig. 12–14.) When the rocket has cleared the guide, a bore-clear mechanism switches

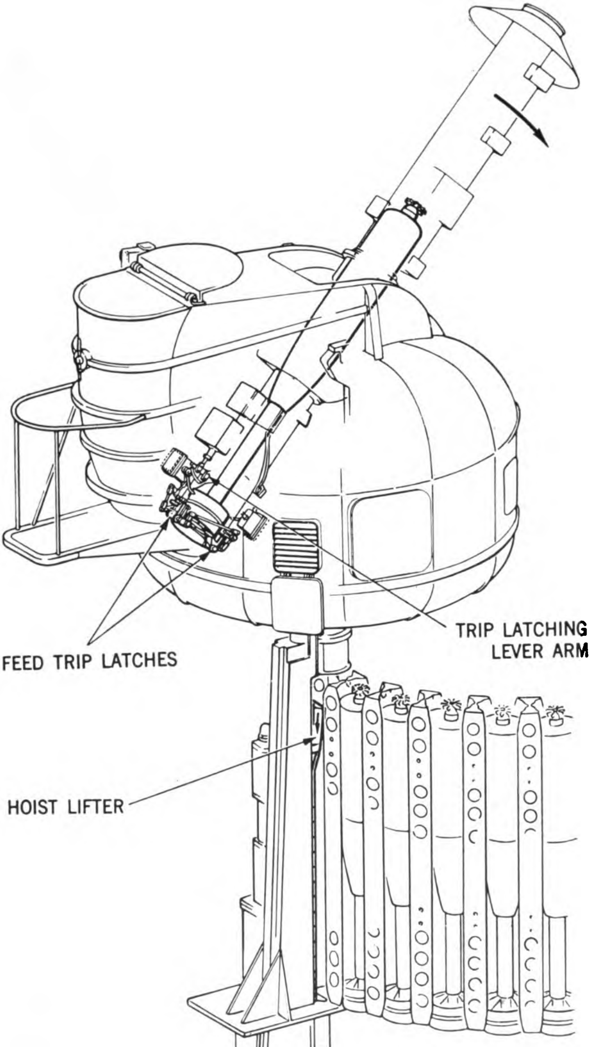


Figure 12–13.—12.75-inch Rocket Launcher Mk 108. Guide moving to firing elevation; hoist moving down.

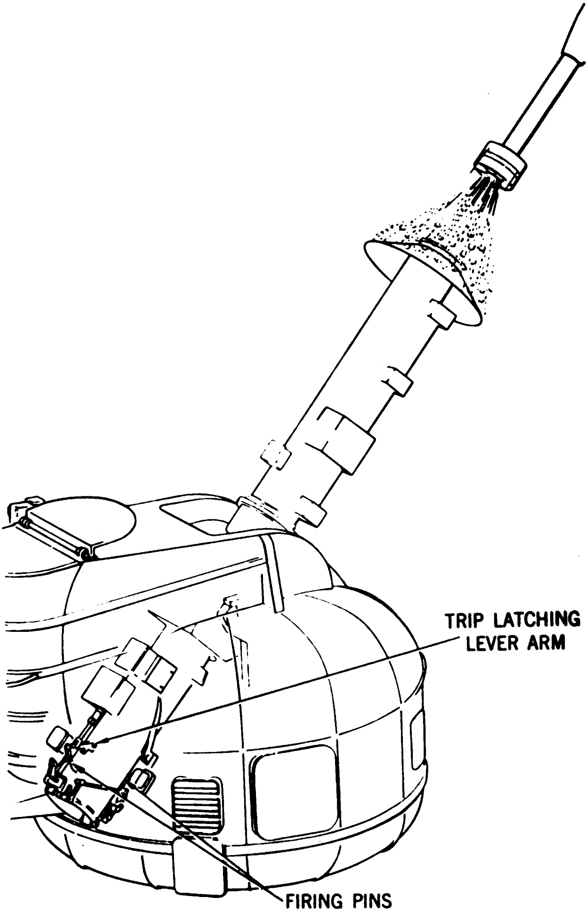


Figure 12–14.—12.75-inch Rocket Launcher Mk 108. Rocket being fired.

control from UB Plot to a return-to-vertical director, in response to whose signal the power drive elevates the guide tube to loading position. The cycle then repeats until the firing circuit is opened or the ready-service ring's supply of ammunition is exhausted.

Ready-service ring loading. Loading the ready-service ring is a separate operation from firing, and the two are not performed both at once. Several men are required in the magazine for this operation. A controlman is needed to operate the lower hoist controls; a trolley hoist operator attends each trolley hoist control station; two rocket handlers work with each trolley hoist. The operation is illustrated in figure 12–15.

The procedure is first to release the latch that keeps the tray locked against the lower hoist, then to operate the tray control to lower the tray to the position shown in figure 12–15A. Then, with the trolley hoist, the crew transfers a rocket from stowage to the tray, and removes the shorting clip that prevents stray currents from setting off the rocket motor squib accidentally. (The rocket launcher components through which the rocket travels on its way up to the guide are equipped with shorting contacts to substitute for the clip.) Next, the trolley hoist operator removes the rocket carrier (used with the trolley hoist in transferring the rocket from stowage to the tray). The lower rocket hoist controlman then punches a button on his controls which causes the loading tray to lift to vertical position; the hoist rammer then automatically lifts the rocket up into its berth in the ready-service ring (fig. 12–15B), and descends. The local mount operator operates a switch to rotate the ready-service magazine to the next vacant space in the ring. The process repeats until the magazine is either full or has the ordered number of rockets.

Maintenance of Mk 108 Rocket Launcher

Following is a summary of maintenance operations on the Mk 108 rocket launcher.

Routine upkeep. Lubrication instructions are contained in OP 1754. Be sure that equipment is lubricated in accordance with Bureau of Ordnance lubrication charts.

Use the daily, weekly, monthly, quarterly, semiannual, and biannual routine maintenance check-off lists and the pre- and post-firing check-off lists as guides for complete

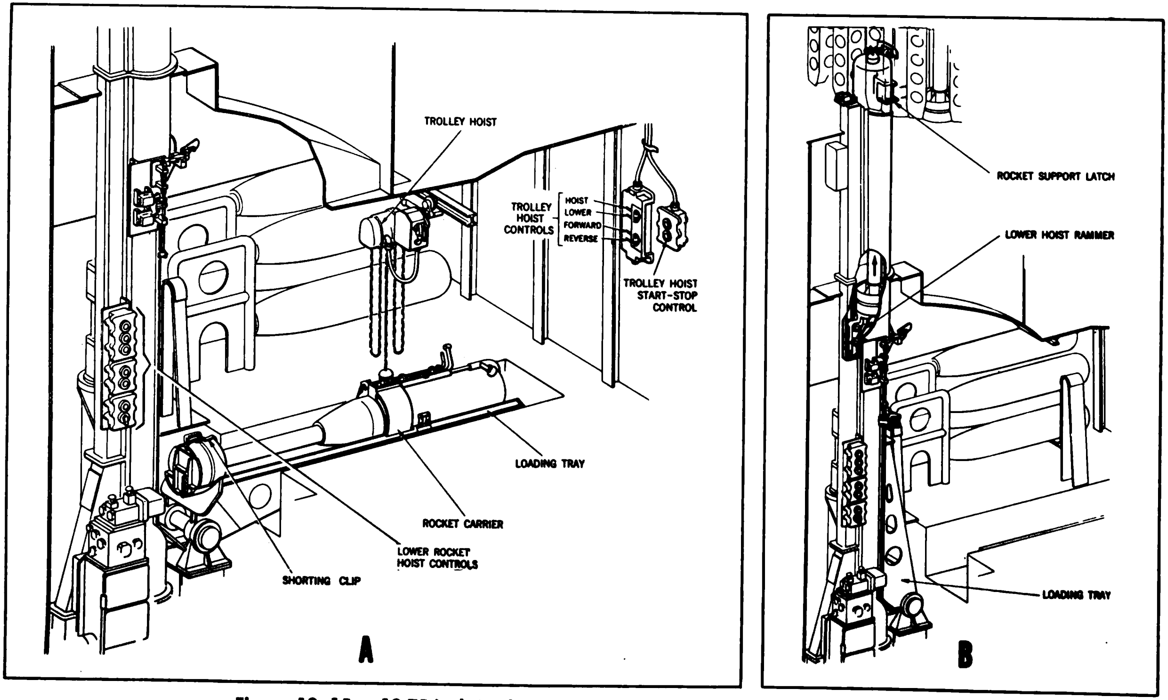


Figure 12–15.—12.75-inch Rocket Launcher Mk 108. Loading the ready-service ring. A. Loading rocket on tray. B. Hoisting rocket into ready-service ring.

and proper maintenance of the launcher equipment.

Exercise the train and elevation power drives every day. Run them through their full range first by hand, then, after thoroughly warming up, under power at very slow speed, into and out of both limit stops. This operation prevents residue from forming, maintains the pliability of seals, and ensures proper operation of valves.

During operation observe quickness of response and general performance. Watch for evidence of valve sticking, binding of parts, or leaks. It is not necessary to operate the drive at high speed during this exercise.

Tools and accessories necessary for maintenance and repairs of launcher equipment are supplied in boxed sets and should be stored in these boxes when not in use.

Adjustments. Adjustments that can be made aboard ship by ship's personnel are described in detail in OP 1754.

Misfire Procedure in the Mk 108 Rocket Launcher

We can't go into details of misfire procedure here, but the main idea is to get the round cooled down and then to jettison it. You don't make any further attempts to fire. The important steps in the process are as follows:

1. Remove the safety plug from the firing panel, elevate the guide to 60°, stop the elevation power drive, and switch the train power drive to local. All personnel must be clear of the mount topside.
2. Align the mount in train with the ejection tray which has been set up next to it, and turn off all remaining power drives and control and firing circuits. Spray the guide tube with water to cool it down.
3. After 30 minutes, the men assigned go topside, carrying the safety plug with them. They crank the guide down to —10°, open the rammer access door at the rear of the mount, and, with the rammer provided, push the rocket out the guide tube through the muzzle.

Safety Precautions with the Mk 108 Rocket Launcher

The 19 precautions below are by no means the only ones you should be concerned with when you are operating or maintaining the Mk 108 rocket launcher, but they are the most important ones. These, of course, are the special precautions that pertain to this mount (though some pertain to other rocket mounts also); they are in addition to, not substitutes for, the general precautions in the Navy's publication entitled *Safety Precautions*.

Of those below, the first 10 are primarily for the safety of personnel; the others are particularly important for keeping the equipment itself in first-class shape, ready to do its part in sinking its subsurface target.

1. Live 440-v leads are exposed when covers are removed from equipment panels, controllers, motor terminal boxes, or connection boxes. Before working on any of these units, be sure to deenergize power circuits at their sources; check the terminals with a voltmeter before touching them. Tag open switches to prevent accidents.
2. If possible, always stow guide and carriage before starting to work on the mount.
3. Always set manual stop switch at OFF and remove safety firing plug from firing panel before starting work on the mount.
4. If a misfire occurs, always cool guide and rocket with sprinkler system. Do not approach the guide for 30 minutes after last attempt to fire.
5. Never allow a rocket to remain in a hot guide without cooling.
6. Always cool a rocket before unloading to ready service ring.
7. Never enter firewall area unless guide has been cooled.
8. Before removing any element of equipment, make certain that both electric and hydraulic power are off.

9. Be sure to bleed hydraulic system to reduce accumulator pressure before breaking any hydraulic connections or servicing ready-service ring or hoist.
10. Never enter firewall area with a rocket in the guide.
11. Never attempt to operate a jammed or malfunctioning component. Shut off power and check for cause.
12. Always deflate guide tube port seal before operating guide.
13. Disengage all manual drives before operating launcher under power.
14. Never attempt casualty correction unless you are completely familiar with the weapon.
15. Make sure safety clip is removed before hoisting a rocket into the ready service ring.
16. Make sure firewall doors are secured before firing.
17. Do not operate the elevation power drive for more than 10 minutes with the guide vertical.
18. Cover the slot in the hoist housing before disassembly or repair operations near either hoist.
19. Be particularly careful to avoid excessive lubrication near electrical equipment, wires, and cables.

This brief summary on the Mk 108 rocket launcher will serve to introduce you to the main features of its construction and routine operation. We haven't taken up such operations as casting loose, stowing, or striking down ammunition. For these details you are referred to OP 1754.

PROJECTOR MK 15 MOD 0

The A/S projector (nicknamed "hedgehog") is a mount, used on DE's and DD's, designed to fire 24 missiles in rapid sequence so that they strike the water in a circular pattern about 200 feet in diameter.

These 65-lb missiles, called projector charges, are not rockets, though they contain their own propelling charges.

The hollow cylindrical tail of the charge fits over a rod or spigot on the projector. When the charge's electric primer is ignited by a firing current through the firing pin in the spigot, it sets off the propelling charge. The gas produced by the burning propellant, as it expands, exerts a downward thrust on the spigot and an upward thrust on the projector charge. Since the spigot is supported by the ship, only the projector charge can yield to this thrust, which it does, thereby being hurled into a highly arched trajectory and into the water. The missile's fuze arms after about 15 feet of travel in the water.

Figure 12–16A shows the forward side of the projector, with the spigots; figure 12–17 shows the process of loading the spigots, and you can see how the charges fit over the spigots. A later course in this series describes the charges in further detail.

General Data on the Mk 15 Projector

Weight of complete assembly, fully loaded (lb)	18,985
Diameter of salvo pattern (ft)	200
Range (mean distance of pattern, yd)	188
Time of flight (sec)	8
Type of fire	Ripple
Interval between firing pairs of rounds (sec)	0.2
Total number of charges per loading	24
Maximum arc of train (°)	360*
Elevating limits (°) from mean position	+30

*This limit applies when a single train stop is installed. Maximum train possible when two stops are installed is 331°.

Reference publication for Mk 15 mounts is OP 1745.

Construction and Main Components of the Mk 15 Projector

As figure 12–16 shows, the projector is a rectangular carriage assembly on whose sloping front side are four transverse cradles, each bearing six spigots. The cradles can rotate in limited arcs of elevation in trunnion bearings. All the cradles are cross-connected so that they are moved in unison by the elevating gear. The rear of the carriage mounts the elevation and train controllers, the

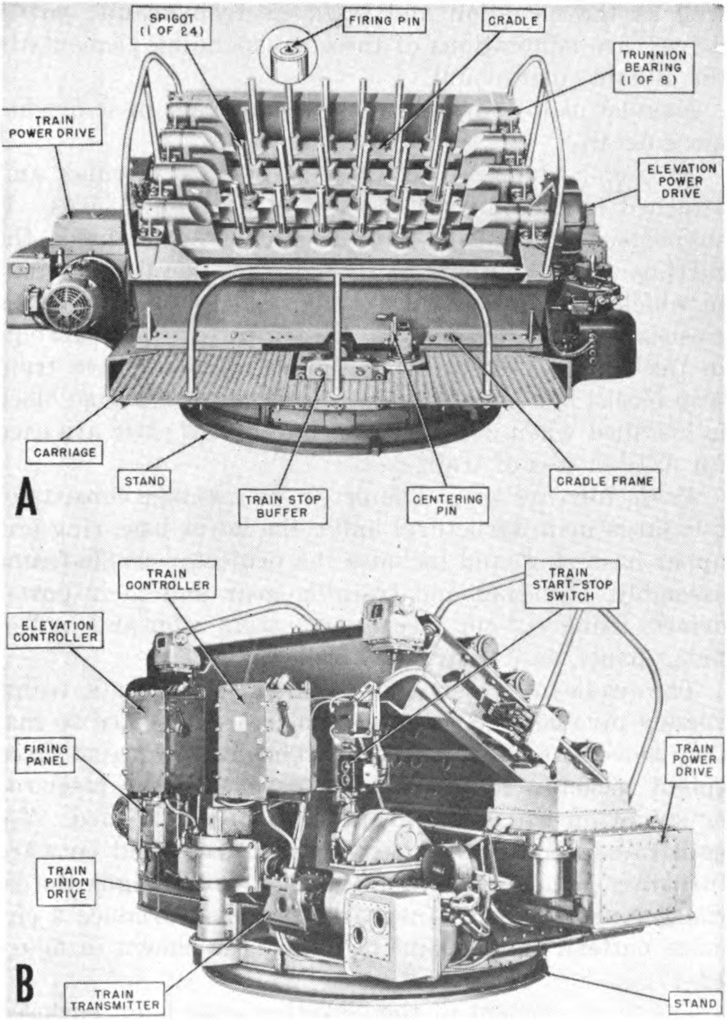


Figure 12–16.—Projector Mk 15 Mod 0. A. Front view. B. Left rear view.

firing panel, and parts of the power drive. The carriage as a whole rotates in train on a stand bolted to the deck. The lower base ring of the carriage, and the stand, as well as the elevation and train electrohydraulic power drives, are adaptations of the corresponding elements in the 40-mm quad mount.

Now let us look at each major component in somewhat more detail.

Projector stand. The stand is a large circular unit attached to the ship's structure by hold-down bolts. It supports all other projector components and holds the carriage down. Others of its parts include the bearings in which the carriage turns, and a fixed ring gear which meshes with a training-gear pinion to turn the carriage in the stand. Associated with the stand are two train stop blocks bolted to the deck inside the stand. One block is installed when 360° of train is required; two are used for 331° or less of train.

Projector carriage. The projector carriage consists of two large main structural units, the lower base ring and upper base ring, and includes the projector cradle-frame assembly, elevating and training gear and their power drives, firing cut-out mechanism, train stop and buffer, firing panel, and electrical installation.

The cradles are four large parallel I-beam units, transversely pivoted in the frame, and cross-connected so that they move as a single unit. Each cradle mounts six fixed spigot sockets. Each socket holds a 14.5-inch steel rod or spigot on which the projector charge is loaded. Together the 24 spigots make up an upward and outward thrusting "hedgehog" arrangement, which aligns the 24 charges so that when they are fired they produce a circular pattern at the point of impact, as shown in figure 12–17.

The main element of the elevating gear is an enclosed worm-and-worm wheel mechanism at the left side of the cradle frame, which can tilt the cradles through a total arc of 60°. The training pinion, which engages the ring gear

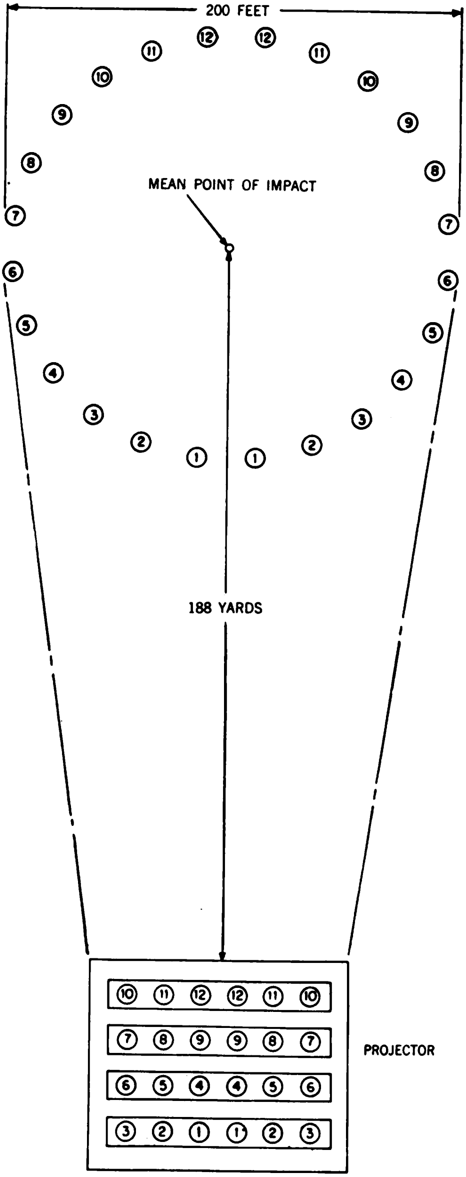


Figure 12–17.—Projector Mk 15. Pattern of fire of a salvo.

in the stand, is driven by a similar arrangement. Both can be actuated either by the hydraulic power drive or manually. Train is limited by the carriage training stop buffer, an assembly of two hydraulic cylinders and pistons which engage the train stops on the deck inside the stand.

The carriage firing cut-out mechanism, a circular cam and follower device that actuates a switch in the firing system, is operated by the train worm drive through a take-off drive shaft. The firing cut-out, like those used with gun mounts, prevents the projector from firing charges into own ship's structure.

Power drives and controls. Elevation Power Drive Mk 5 Mod 20 is an electrohydraulic type almost identical to that used on 40-mm quad mounts. It combines an electric motor driven hydraulic transmission with an electrohydraulic-type receiver-regulator. The train power drive is a similar electrohydraulic assembly—Train Power Drive Mk 6 Mod 14, also derived from 40-mm quad mount equipment.

The train and elevation power drive electric circuits are similar. Both include on-the-mount 440-v a-c electric controllers and motors, and 115-v a-c receiver-regulator synchro units. The power circuits include interlock switches and master pushbutton stations, in addition to the motors and controllers. The 115-v system includes a receiver synchro-control transformer, a lag meter, an amplifier, a starting switch, and a hydraulic transmission stroke-control motor for each of the two power drives. The system works like the 40-mm systems with which you are already familiar.

Firing circuits. Firing a salvo of charges from an Mk 15 projector is different from firing a gun mount or rocket mount, and we'll give it some special attention. The firing circuit (schematically shown in fig. 12–18A) is a remotely operated system that fires the 24 projector charges in pairs at uniform intervals of 0.2 second. Components of the system are Firing Panel Mk 27 Mod 0

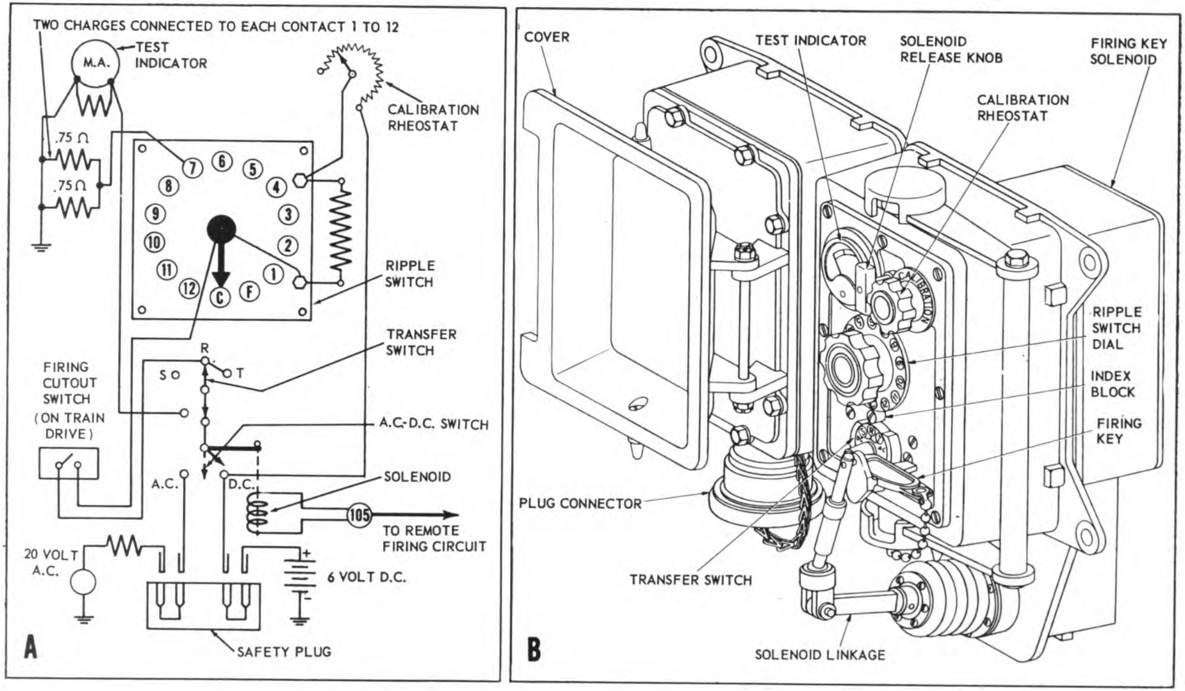


Figure 12–18.—Projector Mk 15 Mod 0. A. Firing circuit (simplified schematic). B. Firing panel Mk 27 Mod 0.

(fig. 12–18B), 24 spigot firing pins, a firing cut-out switch, and a 20-wire connection box. The system is divided into two parts: (1) a firing-current-supply circuit that includes a ripple switch through which the firing current passes to the spigot firing pins, and (2) a remotely operated solenoid that actuates a firing key to start the firing current through the ripple switch. The spring-operated, rotary ripple switch is mounted in the firing panel and must be manually wound up prior to each firing cycle. Included in this circuit is a transfer switch that has three positions, S (Safe), R (Ready to fire), and T (Test). The firing-key actuating solenoid, on the back of the firing panel, is energized remotely from the plotting room. The solenoid armature is linked through a rocker arm to the firing key, which key fits on a square shaft through the center of the transfer-switch dial. When the solenoid is energized, the armature is pulled up and the firing key down to fire position.

The firing panel (fig. 12–18B), which is the main firing control on the projector, provides for proper distribution of the firing current and for testing of the firing pins in each spigot. It houses the solenoid, ripple switch, AC-DC switch, transfer switch, calibration rheostat, and test indicator.

The circuit of each pair of spigot firing pins is connected to a separate contact in the ripple switch, which has twelve live contacts labeled "1" through "12" consecutively, and two dead points labeled "C" and "F" (fig. 12–18A). The numbers indicate which pair of spigots is connected into the firing circuit. "F" is the ready-to-fire position; "C" the dead position after firing is complete. The switch is mechanically interlocked with the transfer switch to permit firing only when the latter is at ready position. Placing the ripple switch in "F" position winds up a spring. A pawl and ratchet device holds it cocked. When the solenoid trips the AC-DC switch, the ratchet releases, and the ripple switch rotates counter-clockwise to "C" position, closing all twelve contacts in succession.

The AC-DC switch connects the firing-pin circuit to either the 20-v a-c or 6-v d-c supply, depending on firing key position. The key may be inserted either (1) with handle to the right (for a-c firing) or (2) with handle to the left (for d-c firing). (This can be done only with the test switch at SAFE.) The solenoid pulls the key handle down to start firing action. This rotates the AC-DC switch to connect the firing current, while a cam on the switch shaft releases the ripple switch ratchet pawl. The solenoid is energized through a separate 115-v a-c circuit by a remote firing key.

The transfer switch is in the firing circuit between the AC-DC switch and the firing cut-out switch. At "S" position the firing circuit is broken, and the firing key may be inserted into the AC-DC switch. With the switch at "R" the circuit is completed. The "T" position, used for testing with the AC-DC switch at DC, has the calibration rheostat and test indicator in the circuit.

The test indicator and rheostat, which are used in testing the continuity of the firing circuit, are respectively a common type of commercial milliameter and a variable resistor. The safety plug, through which both a-c and d-c firing currents must pass, is a safety device that must be kept OUT of its socket except when firing or testing is actually going on.

Operation and Crew Stations of Projector Mk 15

Operation of the Mk 15 projector includes four kinds of activities—preparation, loading, aiming, and firing. Normally, aiming and firing require no personnel at the mount, but up to nine men are needed for preparing and loading.

Preparation, which means getting the stowed projector ready for loading, includes removal of protective canvas covers from the mount and spigots, withdrawal of train centering pin and cradle stowing device, inspection, cleaning, and lubrication before starting, closing power supply switches, starting and exercising the power drives, and testing control, firing, and transmitter circuits. Loading requires placing 24 explosive charges on the projector spigots. Aiming is normally remote-controlled from the plotting room; manual operation is intended for maintenance only. Preparation to fire includes selecting the firing circuit supply, winding up the ripple switch, and, finally, after the crew is clear, installing the safety plugs and closing the remote firing key. This operates a solenoid which releases the ripple switch, and the 24 spigot pins are energized in pairs at intervals of 0.2 second. All charges are cast within 2.2 seconds, and the final position of the ripple switch opens the firing circuit so that the mount cannot be fired again until the switch is reset manually.

This firing method is the only one possible with this weapon, but there are two methods of elevation and train: AUTOMATIC CONTROL and HAND DRIVE. Normally, the projector is trained and elevated in automatic control by the power drives, which are controlled remotely by signals from a plotting room director or from a manually controlled train indicator-regulator near the mount. Hand drive is a manual method of elevating the cradles and training the carriage, for lubrication and service maintenance only.

The on-mount crew for the Mk 15 projector includes a mount captain, two first loaders, two second loaders, and two or more ammunition passers (as required).

The mount captain's duties are essentially the same as those of the crew leader in any other form of gunnery. He supervises preparations for operation, loading, and reloading. He sees that all safety precautions are observed. He checks the condition of the mount and ammunition before firing, and when satisfied that the projector is correctly loaded he personally performs the firing-preparation action, selecting the firing current supply, winding the ripple switch, and setting the train and elevation switches for power operation. He must then report "All clear and ready for firing" to the plotting room.

When the firing circuit has been closed, the mount captain reports to the plotting room as to successful launching or misfire of all 24 charges. In the event of misfire he must, after taking the necessary precautions, reset the ripple switch to repeat firing. After this, he must again report to the plotting room. He also supervises circuit testing procedures before and after reloading the projector. At the end of firing operations he supervises securing the mount.

As shown in figure 12–19, each first loader receives a projector charge from the second loaders, lowers it gently into a spigot, then rotates it a full turn to ensure good electrical contact between firing pin and cartridge primer. Each first loader, when ordered by the mount captain, removes the fuze caps and safety pins from the 12 charges that he has loaded. This is done after the firing circuits are checked with spigots loaded.

Each of the two second loaders has different duties in preparing the mount for operation and in loading.

The second loader at the right of the mount secures the carriage in train during loading, and transfers projector charges from an ammunition passer to the first loader on his side. When both first loaders are clear, after loading, he releases the train centering pin. The second loader at the left of the mount locks the cradles during loading, and passes projector charges to the first loader on his side. After loading is completed and both first loaders are clear, he unlocks the cradles.

The ammunition passers break out the charges from the ready-service lockers, inspect them, and pass them to the second loaders. In addition, one ammunition passer acts as starting controlman to operate both the train and elevation controllers, closing the disconnect switches when ordered by the mount captain.

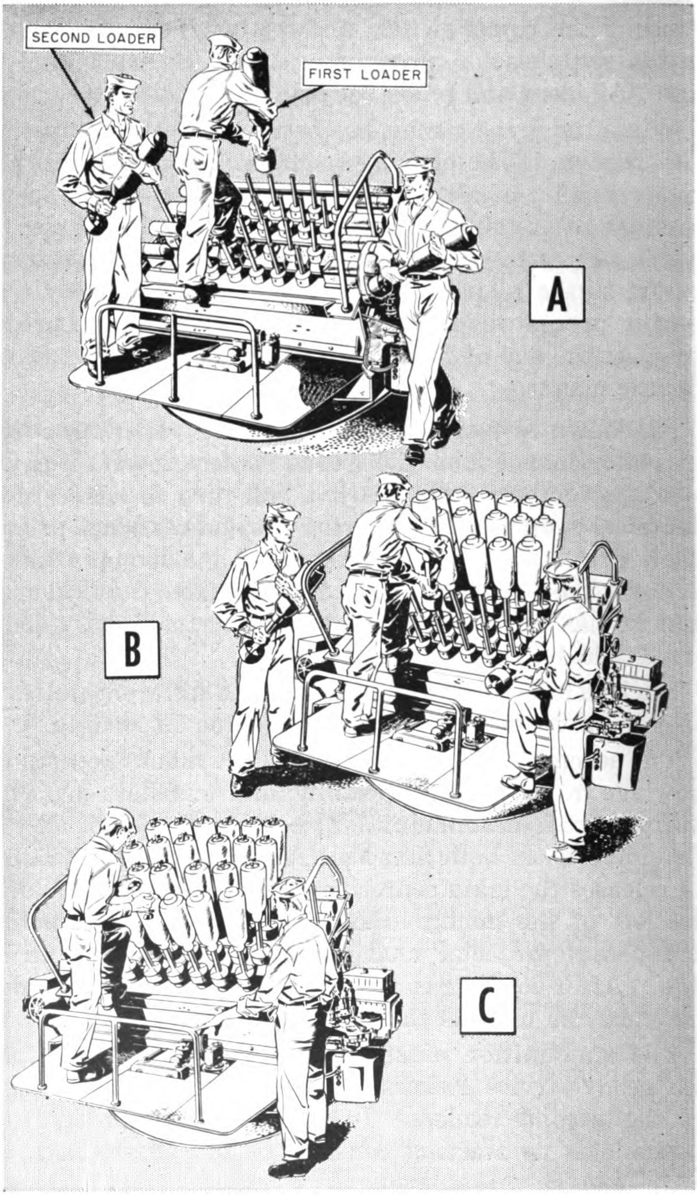


Figure 12–19.—Projector Mk 15 Mod 0. A. Loading upper spigots. B. Loading lower spigots. C. Removing fuze caps and fuze safety pins.

If cradles or the carriage must be manually driven to stow them in preparation for loading, ammunition passers operate the handcranks.

Maintenance of Mk 15 Projector

The projector, because of its exposed position and lack of shielding, requires careful routine upkeep, especially in lubrication. Follow the lubrication charts carefully, particularly for items which must be lubricated daily, weekly, and before or after firing. But avoid excessive lubrication, which can damage electrical parts, and cause puddles on the deck that make for hazardous footing. Don't lubricate fire-control gear; that's for the FT to deal with.

Be sure to open drain plugs periodically to avoid accumulations of moisture and contaminated lubricants.

Periodically check mechanical and electrical parts as called for by the OP. Check over and exercise the power drives; they are similar to the drives you are already acquainted with in 40-mm mounts, and have similar requirements.

Fire-control transmission checks should be performed as required by the ASW or gunnery officer.

Misfire Procedure and Safety Precautions with Mk 15 Projectors

In the event of a misfire, the misfiring charge will remain on its spigot after the others have departed. If this happens, hold the firing key down, operate the ripple switch clockwise through its full rotation, then release it. If the charge still doesn't fire, treat it as a hangfire. Keep all personnel at a safe distance, and, if possible, delay further operation for at least 30 minutes after the last attempt to fire while the projector is kept trained on a safe bearing. Then remove the safety plug from the firing panel. After this interval, remove the defective round and dispose of it as recommended by bomb disposal personnel. If in doubt, give it the deep six.

Safety precautions not relating to assembly of projector ammunition are given below:

1. Don't do any work on the ammunition, especially in fuzes, except under the direct supervision of qualified personnel. Set questionable rounds aside. For information on ammunition, see OP 1001, OP 1745, and OP 1017.
2. Leave fuze caps and safety pins on the ammunition until just before firing, and don't discard them when they are removed. Replace them if firing is no longer imminent.
3. Never leave the projector loaded while the vessel is in port.
4. Always keep the cradle locking device and the train centering pin locked except when actually using the projector. And keep them locked during loading. Release them for any train or elevation movement.
5. Do not tilt the cradles unless at least half of the spigots on each cradle are loaded. Never tilt cradles while personnel are inside the cradle frame.
6. Maintain a safety watch whenever the mount is to be trained, except at general quarters.
7. Never shift the elevating gear or the training gear to hand drive while the mount is moving. And always verify that the mount and the signal are synchronized before shifting to power drive.
8. Live 440-v leads are exposed whenever controller, motor terminal boxes, and some equipment covers are open. Disconnect all power supply switches if electrical equipment is being worked on. Tag switches when men are working on the equipment. Never leave a power switch ON if leaving a control point to investigate power failure.
9. Always open the 440-v power drive supply at each controller whenever personnel mount the projector to load or do any maintenance work.

10. Always keep the safety plug and the firing key out of their receptacles except when actually firing or testing. Always remove the safety plug and firing key before circuit testing a loaded projector. Remove the plug also before shifting the test switch from its test position to S (safe).
11. Remove charges from spigots before testing any of the electrical circuits except when making the routine circuit test prior to firing. (For details on performing tests, see the OP on the equipment.)
12. Keep all personnel away from the blast area when either the safety plug or the firing key is inserted into its receptacle while charges are on the spigots. And always keep the firing panel and safety plug dry.
13. Whenever firing circuit or panel wiring is serviced or replaced, check it by performing all tests for the unloaded projector.

PROJECTORS MK 10 AND MK 11

The A/S projectors Mk 10 and Mk 11 are similar to the Mk 15 in general principle, and resemble it in most details of construction and functioning. Here we'll concentrate on the differences.

Characteristics and Construction

Like the Mk 15, the Mk 10 and Mk 11 projectors fire charges from 24 spigots, and these land in a roughly circular pattern, but the spigots are mounted on four I-beam cradles which are parallel to the length of the mount instead of transverse to it. The salvo pattern is an ellipse about 140x120 feet for the Mk 10 and Mk 10 Mod 1, and a circle about 200 feet in diameter for the Mk 11. Range to the center of the pattern is 200 yards for Mk 10 and Mk 10 Mod 1, 188 yards for Mk 11. But the mount base frames do not train; instead they are secured to the deck. A certain amount of "train" is possible by tilting the trunnion-mounted cradles; they are joined at the after

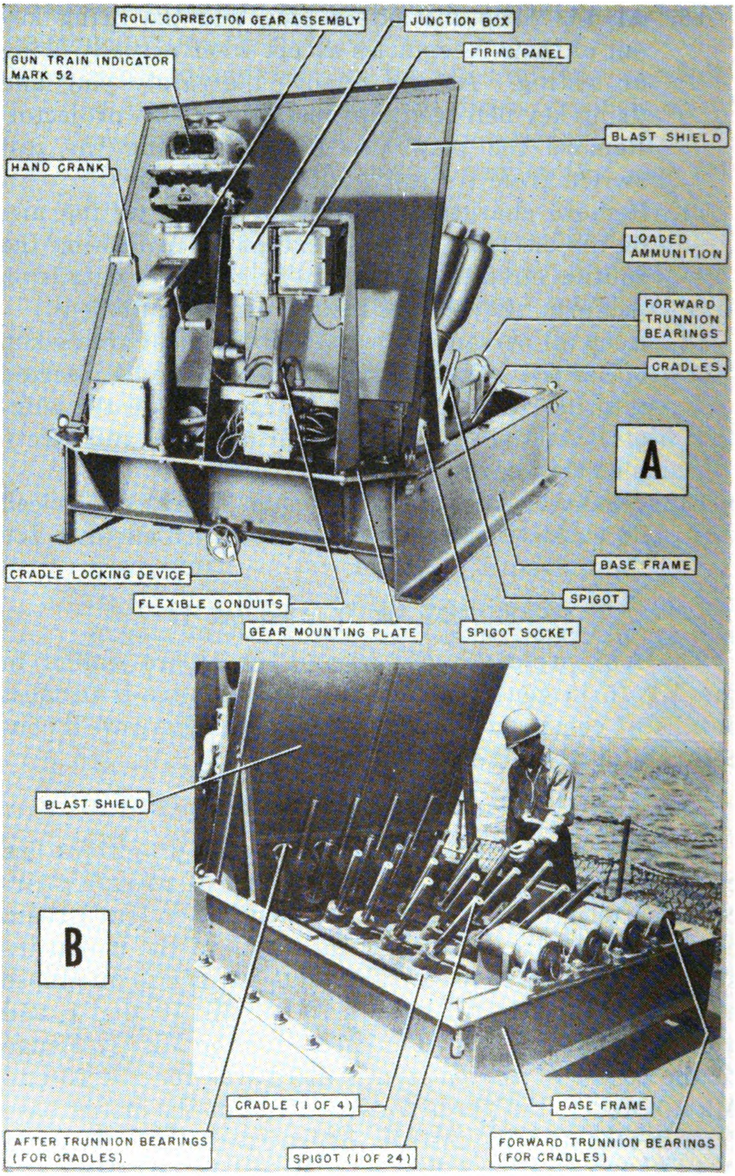


Figure 12–20.—Projector Mk 10 Mod 1 or Mk 11. A. Rear. B. Front.

end by a connecting bar linked to a hand-driven roll correction gear assembly (fig. 12–20). Naturally, the pattern is distorted when the cradles are tilted; the pattern flattens and approaches a straight line at full tilt. Therefore the ship as a whole is aimed so far as practicable, and the tilting is used to make minor corrections.

Mk 10 and Mk 11 projectors are about 91 inches long, 67 inches wide, and 75 inches high, and weigh about 6,600 pounds fully loaded. The reference for Mk 10 and Mk 11 mounts is OP 1001, which also covers their ammunition.

The on-mount accessories used with the Mk 10 and Mk 11 projectors are a firing panel and a gun train indicator; an off-mount target designation transmitter controls cradle tilt. These are discussed further in the following paragraphs.

Mk 10 and Mk 11 Projector Mount Equipment and Operation

In general, the mount operations for the Mk 10 and Mk 11 projectors resemble those for the Mk 15, so far as loading and firing are concerned, though there are some differences in fire control.

The actual direction of fire with respect to the ship is determined by the off-mount target designation transmitter, which receives own-ship's course electrically from the gyro compass, receives gun train order (true target bearing plus lead angle) cranked in manually by its operator, and through gearing converts train order to cradle tilt angle. The transmitter operator corrects for yawing of the ship by keeping his pointers matched. The tilt signal is transmitted by synchro to the gun train indicator.

The gun train indicator on the mount is located behind the blast shield just above the roll correction gear assembly. It contains a gyroscope which with a pointer continuously indicates true vertical while in operation, and, as a standby for this purpose, a bubble-type level tube (fig. 12–21). The tilt order synchro signal from the transmitter is fed to a synchro receiver, whose rotor moves a pointer over the gyro scale. The mount train operator manning the roll correction gear works the handcrank to tilt the cradles; this through gearing also rotates the stator of the synchro receiver, and hence the tilt pointer. Thus, as he matches the gyro pointer with the synchro-driven tilt pointer, the operator corrects for ship's roll and keeps the cradles tilted at order angle. If the gyro should fail, he uses the level bubble instead of the gyro pointer. In the event of synchro failure, the

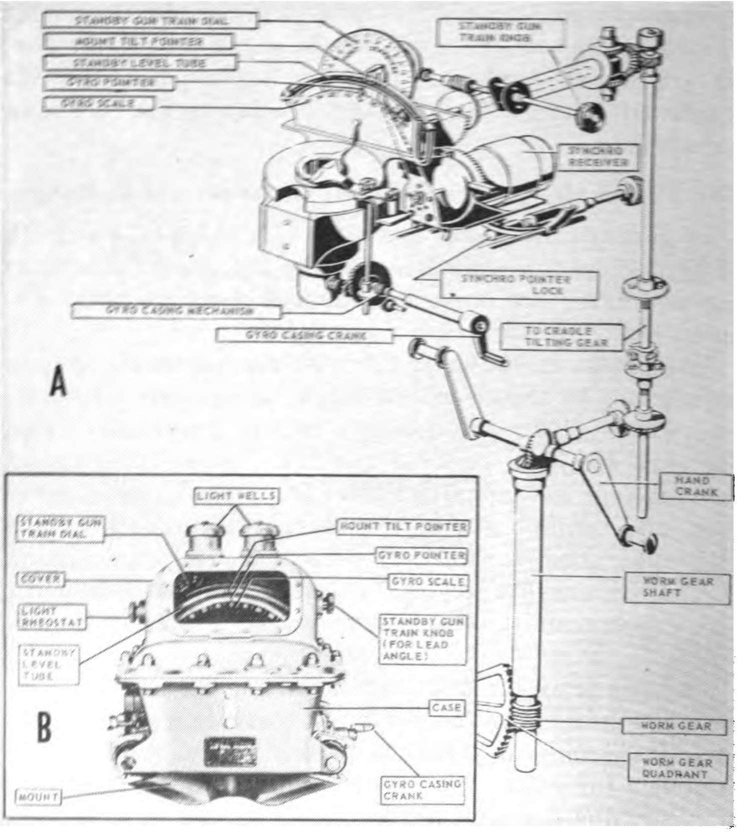


Figure 12–21.—Projector Mk 10 Mod 1 or Mk 11. Gun Train Indicator Mk 52. A. Face. B. Internal schematic.

synchro receiver can be locked and tilt can be manually introduced through the "standby gun train knob." Except when actually in use, the gyro must be kept "caged" or locked by setting the handcrank.

The firing panel on the mount looks and works much like the one on the Mk 15 (fig. 12–22). The test indicator and calibration rheostat are used in testing the firing circuits. These tests are made both before loading and after loading but before firing. The spring-driven ripple switch closes the firing circuit sequentially by pairs to the 24 charges in 12 stages. The switch is wound up by turning it clockwise to F, and rotates through its cycle when released by depressing the firing key.

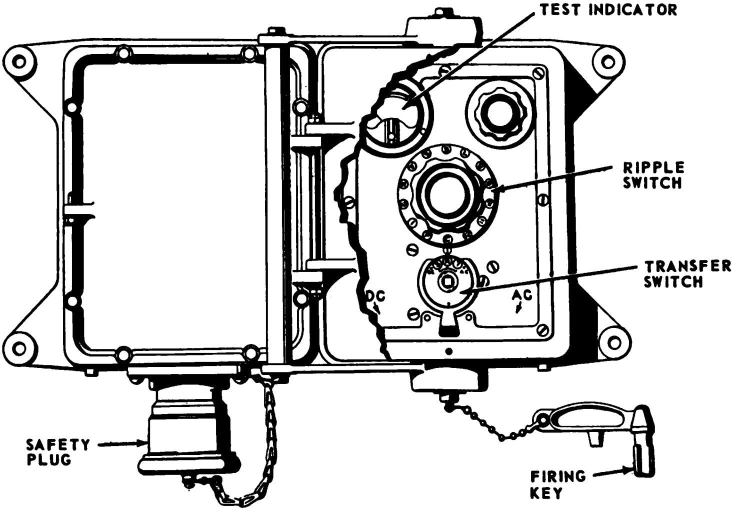


Figure 12–22.—Projector Mk 10 Mod 1 or Mk 11. Firing panel.

The key fits onto a square shaft in the middle of the transfer switch for firing and testing. When inserted with handle to the right, it sets the firing system for a-c firing (from a transformer) ; with handle to the left, the firing circuit operates on d-c from a battery. Depressing the key closes the firing circuit and releases the ripple switch. Except for actual firing and testing, the key must be removed from the firing panel, even for operating the transfer switch.

The transfer switch has three positions—safe (S), test (T), and fire (F).

A safety plug opens the firing circuit when removed from its receptacle.

Mount operations, in summary, are as follows:

1. Before loading, the mount must have been lubricated and firing circuit tested.
2. Ammunition passers inspect the charges for satisfactory condition, then pass them to the loaders, who load them on the inboard cradles first and work outward. Each charge must be spun 360° on its spigot to ensure good contact with the firing pin. The cradles are locked on zero tilt during loading, the transfer switch is on S, and the safety plug is out of its socket.
3. If time permits, the mount train operator then tilts the loaded cradles both ways into their stops to verify that there is no interference. Then the fuze caps and fuze safety pins on the ammunition must be removed. Save the caps and pins; if the ammunition is not fired they can be replaced. But they are NOT to be replaced if through accident the fuzes become armed. After loading, ALL personnel must retire behind the blast shield.
4. Meanwhile the gun train indicator should be energized and the gyro uncaged by turning the caging handle COUNTERCLOCKWISE (never clockwise). See that tilt angle order is coming in from the transmitter.
5. Next, insert the safety plug in firing panel, test primer circuits, set the transfer switch as necessary, the tilt cradles to order angle, insert the firing key, and set (wind up) the ripple fire switch.

6. On signal, FIRE by depressing the firing key. Keep the key down until the ripple switch stops. If necessary, reset the ripple switch and repeat fire to clear all charges off the spigots. Then remove the key and safety plug. Lock cradles at zero tilt, and reload and prepare for another attack if ordered.
7. To secure the mount, lock the cradles at zero tilt, cage the gyro and deenergize the gun train mount indicator.

Maintenance of the Mk 10 and Mk 11 projectors is like that for the Mk 15, only simpler. (There's no power drive to worry about.) It's especially important to keep electrical parts dry and to perform lubrication as required by OP 1001.

Safety Precautions with Mk 10 and Mk 11 Projectors

Safety precautions with Mk 10 and Mk 11 projectors are pretty much the same as those for the Mk 15, except that those relating to power drives and training gear don't apply.

SUMMARY

In this chapter we have taken up the two important power-operated rocket mounts and the three A/S projectors presently in use in the Navy. See the OP's on these weapons for details on mount operations (for example, firing circuit tests in the projectors) that we haven't been able to go into here. And keep your ears and eyes open for new developments in A/S ordnance; they are going on all the time, and some of them will have to do with your job.

In the next chapter we're going to concentrate on something rather different from what you've been studying in this one—small arms and landing party gear.

QUIZ

In the following multiple-choice questions, select the one BEST answer.

1. Which of the following weapons taken up in this chapter is NOT designed for use against submarines?
    a. Mk 102 rocket launcher
    b. Mk 108 rocket launcher
    c. Mk 10 Mod 1 projector
    d. Mk 15 projector
2. When they move into firing position from loading position, the Mk 102 rocket launcher guide tubes are stopped at firing elevation by
    a. the mount firing stop mechanism
    b. a solenoid-operated valve which shuts off hydraulic fluid to the hoist operating cylinder
    c. the amplified elevation order signal from the director
    d. the shoulder of the mount cradle
3. In the Mk 102 launcher's Amplidyne train power drive (fig. 12-2), the Amplidyne motor-generator unit is driven by
    a. mechanical response from the elevation or train gearing.
    b. the synchro signal from the director
    c. the 440-v a-c ship's supply
    d. d-c from the train motor

In the following group of questions on Mk 102 launcher firing components and circuits, match the items in the left column with their proper locations in the right. Note that locations may apply to more than one item, and some locations given are not applicable at all.

4. Firing panel
5. Emergency stop switch
6. Firing stop mechanism
7. Mk 9 relay
8. Intervalometer
9. Firing interlock switch
10. Firing contacts

a. Hoist structure in handling room
b. Handling room bulkhead
c. Rocket guide tubes
d. Carriage
e. Fire-control director
f. Elevating shoulder
g. Underwater Battery Plot

In the following multiple-choice questions, select the one BEST answer.

11. Through which of the Mk 102 rocket launcher firing circuit components do BOTH 115-v and 20-v firing currents pass?
    a. Intervalometer
    b. Mk 9 relay
    c. Firing transformer
    d. Firing stop switch

12. Which of the following components is NOT a part of the Mk 108 elevation or train power drives or controls?
    a. Electronic amplifier
    b. Synchro
    c. Stroke motor
    d. D-c drive motor

13. During which part of the automatic firing cycle of the Mk 108 rocket launcher must the lower hoist operate?
    a. While the guide tube is at loading position
    b. When a vacant pair of rocket ways is aligned with the lower hoist
    c. When the firing signal is transmitted from UB Plot
    d. None of them

14. The function of the trip latching lever arm in the Mk 108 rocket launcher guide tube is to
    a. keep the rocket from drifting toward the muzzle
    b. keep the rocket from sliding toward the breech
    c. latch the guide tube to the rocket hoist
    d. latch the hatch cover closed when the guide tube moves toward firing position

15. In the Mk 15 projector the spigots
    a. can be trained by tilting
    b. can be elevated by tilting
    c. can be tilted individually
    d. cannot be trained or elevated

16. In the Mk 15 projector's firing panel, the ripple switch is moved from C to F position by
    a. being wound up manually
    b. the unwinding of a spring
    c. the action of a solenoid
    d. functioning of the transfer switch interlock

17. At extreme angles of cradle tilt, Mk 10 and Mk 11 projector patterns tend to become
    a. circles
    b. arcs of circles
    c. ellipses
    d. straight lines

18. In Mk 10 and Mk 11 projectors, operation of the roll correction gear rotates the
    a. gyro caging device in the gun train indicator
    b. synchro rotor in the target designation transmitter
    c. synchro stator in the gun train indicator
    d. mount training gear

CHAPTER 13

SMALL-ARMS WEAPONS AND LANDING PARTY GEAR

INTRODUCTION

In the preceding course of this series, you learned in general about the functioning principles of small-arms weapons, and in some detail about the M1 rifle and the M1911A1 pistol. The content of this chapter is built upon what you have learned, and adds to it detailed information on the construction, functioning, and maintenance of other small-arms weapons used by naval personnel, and on how to use landing party equipment. Along with chapter 14, on small-arms ammunition and automatic weapons, you will find the information in this chapter useful if you are assigned to armory work on a ship or in the CB's, or if you are assigned as a small-arms instructor. These chapters will help you also in assignments that require you to repair or maintain small-arms weapons, or to instruct others in their use or maintenance, or to instruct in or take charge of landing party drills and operations.

Scope of This Chapter

The coverage of each weapon discussed in this chapter and in chapter 14 depends on several factors—particularly its complexity, its probably importance to you as a maintenance problem, and its probable importance in connection with training of other men in its use. Some weapons are, for lack of space, or because you have studied them before, treated rather briefly. In these and all other cases, see the reference publications for further information. For parts list references on all weapons taken up in this chapter except shotguns, see NavOrd List 0 (zero), the *Index of NavOrd Allowance Lists.*

You already know how to field-strip, clean, and perform routine upkeep on small-arms weapons, and this will not be repeated. The additional maintenance work you are expected to do is mostly inspection, gaging, and parts replacement if practicable.

The type of repair operation that in the Army would be performed by a highly specialized arsenal or in civilian life by a factory is not covered here. If you are on a repair ship where such work is done, you will be given the training, tools, and study materials to learn it. Where tools, repair parts, and qualified personnel are not available, defective weapons should be returned to the issuing activity for replacement.

Supplementary Sources of Information

In this chapter and in chapter 14 following, you will notice frequent reference to Army field manuals (FM's) and technical manuals (TM's) as sources of additional technical information. As you know, FM's are designed for the "using troops"—the men to whom the weapons are issued. FM's describe weapon construction, operation, functioning cycles, field-stripping, and routine upkeep and cleaning, and contain information on tactical use of the weapon, marksmanship, "immediate action" in case of stoppages, drills, and so on. TM's go into complete disassembly and reassembly, detailed inspection and testing, repair and reconditioning, and detailed gaging.

Two TM's of general use in the armory and small-arms repair shops are TM 9–2200 and TM 9–2205. The first of these reviews catalog-fashion all the hand and shoulder weapons used by the Army. The second is a textbook on the elements of small arms construction and functioning.

You may also find useful TM 9–2210, on small arms malfunctions, with descriptive text and some photographs that will serve as a graphic reminder to remember your safety precautions.

With respect to specific weapons, this chapter and chapter 14 are intended to give you the information on inspection, gaging, and parts replacement that you will normally need in a ship's armory or small-arms repair shop. But FM's and TM's should be available if needed. Check the publications requirements list (specified in OP 0) to be sure that all required publications are aboard.

The *Landing Party Manual,* a special publication issued by the office of the Secretary of the Navy, is a sort of encyclopedia of ground military operations as they apply to ship's landing parties. You'll find this publication particularly useful to supplement the content of this and the following chapter in supplying information on marksmanship exercises, target practice arrangements, organization and drill of the landing party, practice throwing of hand grenades, and proper use of landing party gear other than weapons. See this manual also for information on rifle grenades, which are not taken up in this chapter.

The Leatherneck Association publishes the *Handbook for Marines,* a Marine equivalent of your well-known *Bluejacket's Manual.* If this is available aboard your ship or station, you'll find it a valuable source on elements of small-arms weapon construction, operation, functioning, and maintenance, on using hand and rifle grenades, and on landing party gear other than weapons.

Your whole job in this line will be much simplified if there's a complement of Marines aboard your ship, because they'll be incorporated into the landing party, and they're trained to be experts in the subject matter of this chapter and chapter 14. Their know-how can considerably improve yours. But remember that you're still supposed to be the expert on weapon maintenance and repair, and that you're responsible, Marines or no Marines, for demonstrating your competence in this field, as in others, as the Qualifications for Advancement in Rating require.

SMALL ARMS REVIEW

Before we take up the small arms to be discussed in detail in this chapter, let's very briefly review the general types of small arms and their principles of functioning, which you learned in the course preceding this one.

SHOULDER WEAPONS are those that are generally braced against the shoulder when fired. These include carbines, rifles, shotguns, and submachine guns. The pistol and revolver are the only common weapons in the U. S. Navy normally fired when hand held without being braced against the shoulder, though other weapons can be fired that way.

The line-throwing gun is not a weapon, but is classed with the shoulder types.

LIGHT MACHINE GUNS can be hand carried to any location a man can go, but are normally fired from tripod or bipod mounts. The Browning automatic rifle (BAR), though it can be fired from the shoulder, is usually fired from a bipod and is considered (from the tactical point of view) a light machine gun. The other light machine guns (MG's) are the caliber .30 and the caliber .50 which are designed for firing from mounts. (Ground troops call the caliber .50 a heavy MG, but for our purposes this nomenclature applies to the 20-mm and 40-mm.)

All modern small-arms weapons (except revolvers, caliber .22 rifles, and most shotguns) are loaded and their empty cases ejected by mechanical devices powered by the energy of the burning propelling charge. This mechanical action may be either AUTOMATIC or SEMIAUTOMATIC.

Small-arms weapons are either manual (single-shot), semiautomatic, or automatic in functioning. The line-throwing gun is a single-shot piece; it must be reloaded in a separate operation for each round. A semiautomatic weapon fires once for each squeeze of the trigger and re-loads automatically; an automatic weapon fires continuously while the trigger is squeezed, so long as the ammunition in the magazine or belt holds out.

Automatic and semiautomatic small-arms weapons now in service may be operated either by RECOIL, BLOWBACK, or (propellent) GAS.

In this chapter we shall take up in some detail all the major types of semiautomatic and manual small-arms weapons used in the Fleet at the present time, except the line-throwing gun, the M1 rifle, and the M1911A1 pistol, which you studied in the preceding course in this series. We'll begin with the caliber .22 pistol and work our way upwards by caliber and type. We shall then take up hand grenades, and conclude with a discussion of landing party equipment and how it is used.

CALIBER .22 COLT AUTOMATIC PISTOL

The caliber .22 Colt (Ace) automatic pistol is provided aboard most naval ships and at shore activities for use in training personnel in the fundamentals of small arms and for target practice.

The operation of this pistol is the same as that of the pistol, caliber .45, M1911A1. When fully assembled, they look alike, except, of course, in the size of the bore.

The caliber .22 pistol differs from the pistol, caliber .45, in having a different type of barrel and an ejector which attaches to the barrel. A pistol, caliber .45, M1911A1, can be converted into a pistol, caliber .22, by field-stripping the caliber .45 pistol, removing the caliber .45 barrel, replacing it with the caliber .22 barrel and ejector, and reassembling the weapon.

The magazine is also different from the caliber .45 magazine. It may be charged with any number of cartridges up to ten. It uses caliber .22 long rifle ammunition.

Figure 13–1 shows a field-stripped caliber .22 pistol (right) next to a field-stripped caliber .45. The parts that differ are labeled.

Dimensions, operation, functioning, disassembly, and

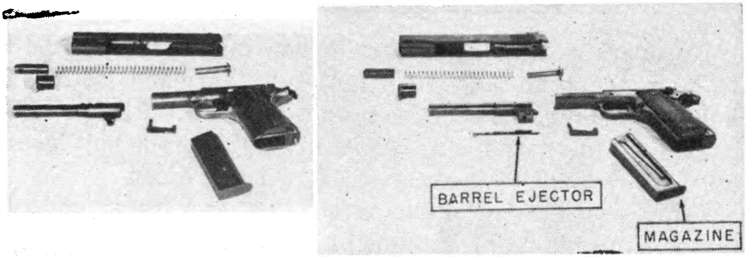


Figure 13–1.—Field-stripped pistols, caliber .45 (left) and caliber .22. The parts that differ are labeled.

assembly of the caliber .22 are similar to those of the pistol, caliber .45, M1911A1, and will not be discussed in this chapter.

Caliber .22 pistols have not been standardized in the Navy so thoroughly as other weapons, and you are likely to come across a few of other designs than this one, including particularly several models by Hi-Standard. If you have to deal with these, see the manufacturer's literature for parts lists and instructions for maintenance and disassembly.

CALIBER .22 RIFLE

The Navy uses caliber .22 rifles of commercial design for marksmanship training purposes. The type used almost universally at the present time is the Mossberg model 44US, a magazine-fed bolt-operated weapon (fig. 13–2A). You should know enough about this rifle to instruct in its operation and to maintain it.

General Characteristics

Length overall (in.)	43
Weight (lb)	8½ approx.
Length of barrel (in.)	26
Trigger pull (lb)	2½ to 5
Magazine capacity (rounds)	7
Type ammunition	cal. .22 long rifle

Operation and Sight Adjustment

To operate the rifle, insert loaded magazine, pull bolt fully to the rear, and push bolt fully forward, rotating bolt lever down. The rifle cannot be fired until the bolt lever is all the way down. After firing, raise the bolt lever and pull the bolt to the rear to extract and eject.

When the red end of the safety indicator (rear end of mainspring plunger) extends outside of the bolt (fig. 13–2B) the action is cocked and ready for firing. When the thumb safety points to red button F in the stock, the trigger can be pulled and the rifle fired. When the safety points to green button S it is on SAFE, and the trigger cannot be pulled.

The rifle is equipped with the Mossberg S100 sight on the receiver. The graduations on the elevation and windage screw knobs represent ½-minute adjustments each. This is equivalent to ½ inch change of bullet impact at 100 yards, ¼ inch at 50 yards, or ⅛ inch at 25 yards. The sight mechanism clicks once for each graduation of adjustment. Remember to move the rear sight in the SAME direction in which the point of impact is to be moved on the target.

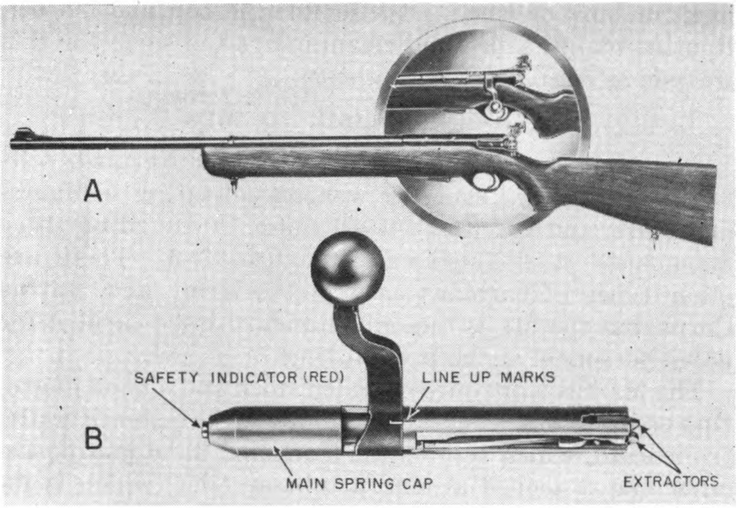
If the rifle shoots low, raise the sight aperture by turning the elevation screw to the left (counterclockwise), marked UP on elevation nut. If the rifle shoots to the left, move the sight aperture to the right by turning the windage screw to the left (counterclockwise), or conversely if the rifle shoots to the right.

Disassembly and Maintenance

The Mossberg model 44US is simple in construction, and requires the same general maintenance measures as other rifles. Disassembly is not difficult.

To remove the bolt, swing windage bracket on receiver sight to left, lift bolt lever, pull bolt fully to the rear, and pull back on trigger. The bolt will slide out.

To disassemble the bolt, place mainspring cap (fig. 13–2B) in vise and using bolt lever for handle, unscrew this



Courtesy of O. F. Mossberg & Sons, Inc.

Figure 13–2.—Mossberg caliber .22 rifle model 44US.
A. General view. B. Bolt assembly.

cap from bolt body. When this is done you can remove the bolt lever, firing pin, mainspring, and mainspring plunger with your finger.

To replace the bolt, line up the marks on the bolt body and locking lever (fig. 13–2B). Insert bolt into receiver, pull back on trigger, and push bolt forward. Never force the bolt; if inserted properly it will slide in easily.

To remove the stock, first remove magazine clip; then loosen takedown screw just ahead of trigger guard, and the front swivel screw (which can be unscrewed by turning the swivel itself). The stock can then be taken off.

Inspection

As with other small-arms weapons discussed in this chapter, inspect caliber .22 rifles at least annually. Check the barrel for dirt, corrosion, rust, leading, and coppering. Check the operating parts for smooth operation, and look for burs or rust. Disassemble the bolt and inspect. Routine maintenance and cleaning are the same for this weapon as for its bigger brethren.

CARBINE, CALIBER .30, M1

The carbine, caliber .30, M1, is a gas-operated, self-loading, air-cooled shoulder weapon delivering semiautomatic fire, and is fed by a 15-round or 30-round box-type magazine. It is illustrated in figure 13–3. There are other types of carbines used in the Army and Marine Corps, but the M1 is the only standard issue carbine for naval personnel at the present time.

The M1 has a one-piece wooden stock and a hand guard. One end of a sling is attached to a swivel fastened to the front band, which retains the stock and hand guard; the other end is looped around a tubular oiler, which is inserted into the right side of the rear of the stock.

The main characteristics of the M1 carbine are as follows:

Length (in.)	35.5
Weight with full 30-round magazine (lb)	6.6
Muzzle velocity (fps)	1,970
Chamber pressure (psi)	40,000
Length of barrel (in.)	18
Maximum range (yd.)	2,200
Maximum effective range (yd.)	300
Rifling	1 turn (right hand) in 20 in.
Trigger pull (lb)	5 to 7

The carbine uses caliber .30 ammunition, which, however, is NOT interchangeable with ammunition for other caliber .30 weapons. Small-arms ammunition will be taken up in detail in chapter 14.

Functioning

The caliber .30 carbine is a gas-operated weapon whose functioning much resembles that of the M1 rifle. Its three main functioning phases are FIRING, FORWARD MOVEMENT of the operating parts, and REARWARD MOVEMENT of the operating parts. During each of these phases several steps of the weapon's functioning occur. Let us take

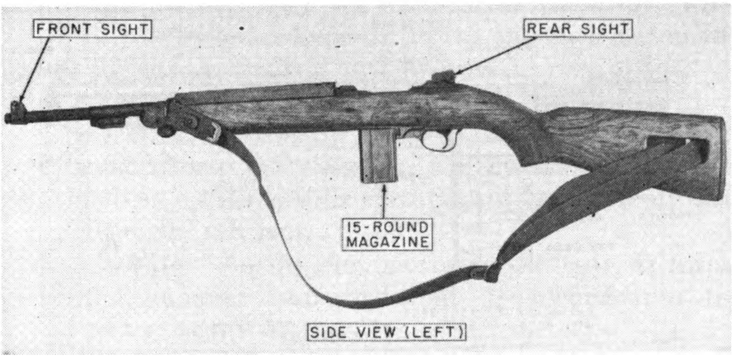


Figure 13–3.—Carbine, caliber .30, M1.

up these functioning phases and the individual steps in each. Follow the general functioning of the operating parts and gas action in figure 13–4.

FIRING. There is but one step to this phase (fig. 13–4A). The gunner squeezes the trigger, the trigger pivots, and the trigger lip lifts the after end of the sear. The sear front end moves downward to disengage the sear notch on the hammer. The hammer spring drives the hammer upward and forward; it strikes the firing pin, which transmits the impact to the cartridge primer and sets it off. All this can occur only if the firing pin's tang is aligned with a slot in the bridge of the receiver (not illustrated); this condition in turn can exist only if the bolt is fully locked and the safety is unlocked (OFF).

REARWARD MOVEMENT. There are nine steps in this phase, as follows:

1. *Gas action.* (See fig. 13–4A.) When the cartridge ignites, the gas formed by the burning powder develops a chamber pressure of approximately 40,000 psi. Most of the gas propels the bullet, but a small part expands through the gas port into the gas cylinder, strikes the piston, and drives the operating slide to the rear, compressing the operating spring.
2. *Action of operating slide and spring.* The operating slide moves to the rear approximately 5/16 inch

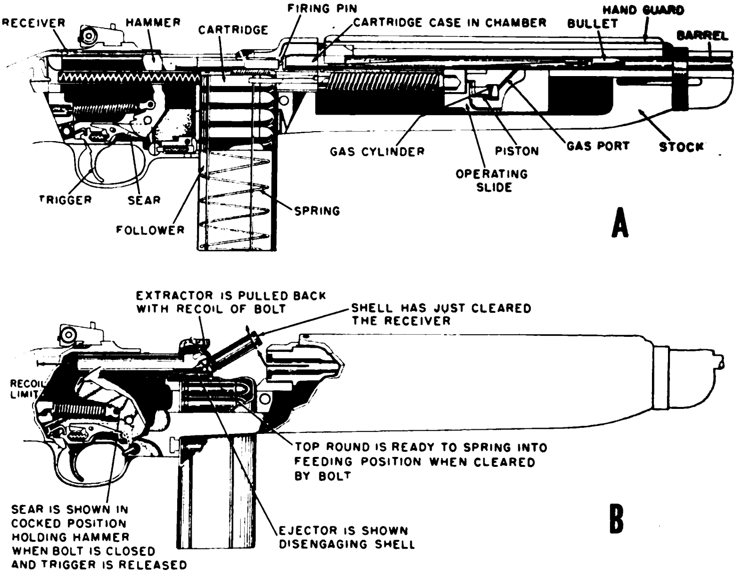

RECEIVER
HAMMER
CARTRIDGE
FIRING PIN
CARTRIDGE CASE IN CHAMBER
HAND GUARD
BULLET
BARREL
GAS CYLINDER
PISTON
GAS PORT
STOCK
OPERATING SLIDE
TRIGGER
SEAR
SPRING
FOLLOWER
A
EXTRACTOR IS PULLED BACK WITH RECOIL OF BOLT
SHELL HAS JUST CLEARED THE RECEIVER
RECOIL LIMIT
TOP ROUND IS READY TO SPRING INTO FEEDING POSITION WHEN CLEARED BY BOLT
SEAR IS SHOWN IN COCKED POSITION HOLDING HAMMER WHEN BOLT IS CLOSED AND TRIGGER IS RELEASED
EJECTOR IS SHOWN DISENGAGING SHELL
B

Figure 13–4.—Carbine, caliber .30, M1. A. Firing and gas action. B. Extraction, ejection, feeding, and cocking.

before contacting the operating lug of the bolt. The delay allows the bullet to clear the muzzle, and the pressure inside the barrel to drop, before the bolt begins to unlock. This prevents blowback of gases into the gunner's face.

3. *Unlocking.* As the operating slide continues to the rear, the front camming surface in the hump of the operating rod contacts the operating lug on the bolt, turning the bolt to unlock it.
4. *Withdrawal of the firing pin.* This action occurs as the bolt is being unlocked. As the bolt turns, the bridge of the receiver cams the tang of the firing pin rearward, withdrawing the striker of the firing pin into the bolt.
5. *Extraction.* (See fig. 13–4B.) The extractor has been gripping the cartridge case rim all the time

that the cartridge has been in the chamber. First the cartridge is loosened in the chamber as the bolt unlocks; as the bolt continues to the rear it pulls the empty case from the chamber.

6. *Ejection.* When the front of the empty cartridge case clears the chamber, the ejector in the bolt, driven by the ejector spring, throws the empty case from the receiver.
7. *Cocking.* As the bolt moves to the rear, it forces the hammer rearward and downward into the cocked position.
8. *Feeding.* When the bolt in its rearward movement clears the top round in the magazine, the follower, through the action of the compressed magazine spring, moves the top cartridge up into the path of the bolt.
9. *End of rearward movement.* This phase ends when the heavy part of the operating slide contacts the front of the receiver.

FORWARD MOVEMENT. This can be considered in four steps, as follows:

1. *Chambering.* As the operating slide and bolt move forward (in counterrecoil), pushed by the compressed operating slide spring, the bolt strips off the top round in the magazine and shoves it into the chamber. When the bolt reaches its forward position, the extractor grips the rim of the cartridge. The base of the cartridge forces the ejector into the bolt, compressing the ejector spring.
2. *Locking.* When the bolt is all the way forward, the rear camming surface in the hump of the operating slide forces the operating lug of the bolt downward, making the bolt rotate clockwise (much as in the M1 rifle). The bolt locks as the lugs on both sides of it engage the locking recesses in the receiver.
3. *Alignment of the firing pin.* Just before the bolt reaches its forward position, the tang of the firing

pin (not illustrated) contacts the bridge of the receiver, stopping the forward movement of the firing pin. When the bolt is fully locked, the tang of the firing pin aligns with the slot in the bridge of the receiver and may be driven forward by the hammer.

4. *End of forward movement.* After the bolt locks, the operating slide continues forward a short distance, and stops when the operating slide has driven the gas piston into the gas cylinder.

Maintenance Inspection and Testing

You are already acquainted with routine small-arms maintenance procedures in general. Carbines should be carefully checked and tested after field stripping and reassembly. Headspace should be checked before going on the range and upon completion of firing. And, in accordance with section B, paragraph 9B2, *Bureau of Ordnance Manual,* each carbine should be thoroughly inspected once a year in any case. The detailed inspection procedure is as follows:

PRECAUTION BEFORE INSPECTING.

1. Hold the carbine with the muzzle pointed at the floor, clear at once, and inspect the chamber for a live round. See that there are no obstructions in bore or chamber. Do not touch trigger until after carbine has been cleared.
2. Before inspection is begun, clean each weapon thoroughly to remove grease, dirt, or other foreign matter which might interfere with proper functioning, or with the use of gages and tools used in inspection.
3. Inspection, maintenance, and repair of the carbine should be thorough and exacting. The malfunction of one small part may cause malfunction of the carbine.

DETAILED GENERAL INSPECTION.

1. Inspect the carbine visually for general condition, operation, and functioning before disassembling for detailed inspection. Use dummy cartridges, if available.
2. Inspect carbine for appearance and general condition as follows:
   a. Inspect barrel and receiver group and hand guard for excessive looseness in stock. Hand guard may have slight movement backward and forward. However, there should be no possibility of its becoming disengaged from the front band or skirt on the receiver. Tight hand guards are likely to push band off when recoil is heavy, as when grenade launcher is used.
   b. Inspect front band and sling swivel for looseness. Band should be held firmly in place by shoulder of locking spring.
   c. Inspect stock and hand guard for cracks, undue scarring, and dried-out wood.
   d. Inspect front and rear sights for looseness.
   e. Inspect oiler for retention in stock, and sling for wear and security on carbine.
   f. Inspect metal parts, including barrel, for rust, corrosion, scoring, and cracks.
   g. Inspect magazine for retention in receiver, ease of withdrawal, undue looseness, dents, rust, and movement of follower.
3. With dummy cartridges in the magazine, retract and release the operating slide, to load and eject the dummy cartridges. During operation, inspect the following points:
   a. *Smooth functioning of operating slide and bolt.*
   b. *Complete locking of bolt, and forward movement of operating slide.* The slide should continue to move forward about 5/16 inch after the bolt is fully locked. The same free movement

should take place at the start of slide rearward movement before rotation of the bolt begins.

c. *Grip of extractor on cartridge and function of ejector.* Extractor should grip base of cartridge firmly. Ejector should throw it off the bolt as soon as cartridge front end is clear of the receiver. If cartridge is not extracted the extractor claw may be damaged, or extractor plunger or spring broken or missing. Failure to eject may be caused by a broken ejector or a weak or broken ejector spring. If dummy cartridges are not available, operate parts individually, and test spring action.

d. *Chambering of cartridge.*. The bolt should chamber the cartridge smoothly when released. If bullet ramp on receiver or barrel is rough, or magazine loose so that it tips forward, the bullet may bind on ramp or be deflected upward during chambering and strike the top of the barrel and cause a stoppage.

e. *Position of cartridge in mouth of magazine.* If magazine follower does not position cartridge fully up against lips of magazine, the magazine spring may be weak or broken, or the tube or follower dented, rusted, or burred, or the magazine incorrectly assembled. If dummy cartridges are not available, depress follower to bottom of tube, then allow it to rise. Inspect for smooth and positive functioning.

f. *Engagement of sear with hammer.* The sear should engage with sear notch in hammer when bolt is about halfway retracted. There should be a crisp click as sear slides forward into the sear notch. Retract bolt fully to insure complete engagement and retention of sear. If click is not heard, or trigger pull appears to be too light or heavy, examine sear and sear notch in hammer for wear, burs, foreign matter in sear notch, or weak or broken sear spring. Trigger pull should not be under 5 pounds or over 7 pounds.

g. *Engagement of sear when trigger is not released.* The sear should engage and hold the hammer when the trigger is held back and the slide is operated rapidly. Test by grasping the carbine by the grip of the stock with the left hand, with index finger on the trigger. Pull the trigger all the way to the rear, and hold. Grasp the operating slide handle with the right hand and move the bolt back and forth rapidly five or six times. Release the operating slide handle in the forward position, release the trigger, allowing it to move fully forward, then pull it again. If the hammer does not fall, it has jarred out of engagement with the sear and followed the bolt forward.

TRIGGER PULL TEST. The object of this procedure is to test trigger pull for smoothness and for pressure exerted. The general procedure described here applies to all small arms, though the weights used will differ. Trigger pull should be clean, without "creep," and smooth in action. ("Creep" means any perceptible movement in the trigger pull between the time the slack is taken up and the time the hammer is released, with pressure applied to the trigger at a uniform rate of increase over a period of at least 10 seconds.) A weapon that fails in this test should be rejected.

In testing carbine trigger pull you will need hooks and weights which will combine to 5 and 7 pounds.

This is the testing procedure (and see fig. 13–5):

1. See that safety is disengaged and pushed all the way to the left, and that carbine is cocked.
2. Have the weights resting on the deck, and insert the hook of the trigger weight wire through the trigger housing guard bow to bear on the trigger so that

pressure is applied 1/4 inch from lower end or tip of trigger.

3. With the barrel of the carbine held vertically, raise the weight from the floor as gently as possible. If the 5-pound weight pulls the trigger to release the hammer, or the 7-pound weight fails to pull the trigger to release the hammer, the carbine has failed to pass inspection. (The only correction you can make is selective assembly of hammer, hammer springs, sear, and/or trigger, or all four, until the required pull is obtained.)

Take care during the test to see that the wire contacts the trigger only and does not rub against the trigger housing or stock, and that wire and axis of bore are perpendicular to the floor. Each time weights are applied to the trigger, cock the weapon again, otherwise the sear may be *partially* disengaged from the hammer. This will result in a false reading next time weights are applied.

DETAIL INSPECTION OF BARREL AND RECEIVER GROUP. This comprises a visual inspection and gaging with headspace gages.

Visual inspection of the carbine's bore requires judgment based on experience. A certain amount of pitting and wear will not disqualify a weapon from use, but, at the minimum, the lands of the rifling must be sharp, and there must be no pit large enough to permit passage of gas past the bullet. A pit the width of a land or groove and 3/8 inch long is therefore large enough to cause rejection. Examine the barrel for mechanical damage and examine the chamber for deep pits that would seriously affect extraction.

Gaging is done with HEADSPACE GAGES. Figure 13–5B illustrates a carbine headspace gage. Figure 13–6B shows how a headspace gage is used—in this case, in a rifle. The headspace of a carbine or other small-arms weapon is the distance between the forward end of the chamber and the forward face of the bolt, when the bolt is in locked position.

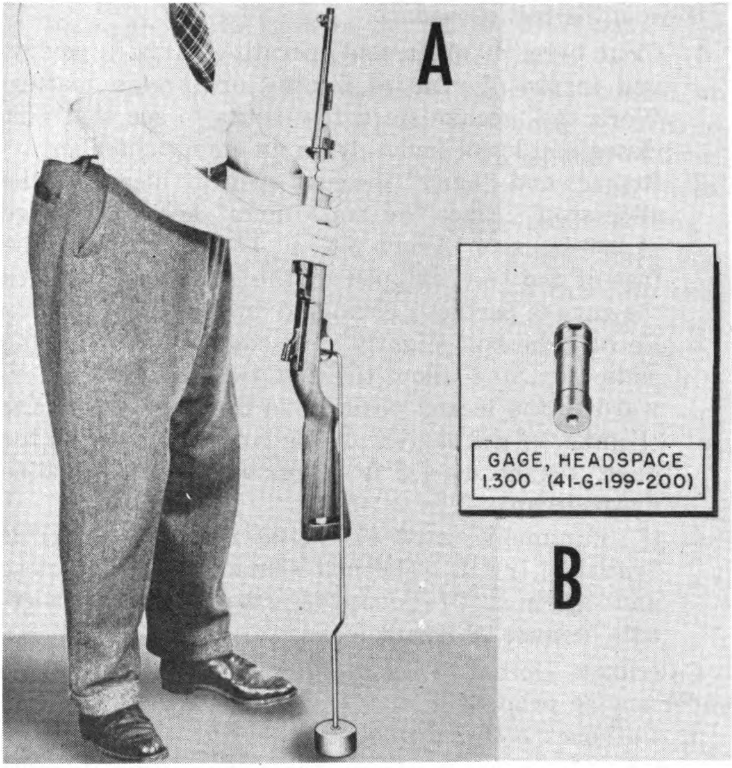


Figure 13–5.—Carbine, caliber .30. A. Testing trigger pull. B. Headspace gage 41-G-199-200 (1.300 in.).

The forward end of the chamber is its shoulder—corresponding to the forcing cone in a naval gun—where the chamber begins to narrow.

If headspace is insufficient, the bolt will not fully lock behind the cartridge without being forced. If headspace is excessive, the cartridge will have too much play in the chamber when the bolt is locked behind it. Either condition is unsafe.

NOTE: Headspace as defined above does NOT apply to the caliber .30 machine gun, which has a unique definition of headspace and a unique method of adjusting it.

Here is the test procedure.

1. Clean bore, chamber, and operating parts, wipe dry, and inspect for metal fouling or foreign matter. Work the mechanism a few times to see that bolt closes and locks smoothly on an empty chamber.
2. Retract and "hang" the bolt open by means of the slide stop. Place the "maximum" headspace gage (1.300-in. size, Army No. 41–G–199–200) on the face of the bolt, gripped by the extractor. Be sure the gage is perfectly clean and dry.
3. Retract the bolt slightly to disengage the operating slide stop, and allow the bolt to move slowly forward to the locked position so the gage enters the chamber of the barrel. If the bolt locks fully on the gage, the headspace is excessive and the carbine unserviceable.
4. If "minimum" gage 41–G–199–175 (1.290 in.) is available, try it. The bolt should completely close and lock on it. If it doesn't the weapon is unserviceable because of insufficient headspace.

CAUTION: Do not force, or allow bolt to close sharply under spring propulsion.

5. Pull back bolt and remove gage.

DETAIL INSPECTION OF MAGAZINE. Test magazine for retention in carbine. Inspect follower for smooth movement in tube under force of spring by depressing follower and allowing it to rise. If follower does not depress and rise smoothly to the top of tube under spring action, look for burs, rust, and corrosion in tube, reversed follower, deformed or burred tube or follower, the weak, broken, or reversed spring. Apply pressure evenly on the follower when depressing in order not to "cock" or rotate it in the tube.

DETAIL INSPECTION OF ADJUSTABLE REAR SIGHT

1. Inspect sight assembly generally for rust, dents, burs, and foreign matter, looseness of moving parts, and looseness of assembly on the carbine. The sight

base should be tight in the receiver. There should be no unnecessary play in moving parts.

2. Check sight base for looseness and bent, burred, or shiny wings. Check ramp for worn or burred guideways and index ball retention notches in floor. Check notches for foreign matter. Check index plate on rear face of ramp for security and setting.
3. Check windage screw for wear of threads, burs, and looseness, security, and staking. With ramp centered in sight base, press windage screw knob to left and release, to test spring action of index ball on knob.
4. With ramp centered in sight base, attempt to move lower end of ramp from side to side. There should be practically no lateral movement. If very noticeable movement is present, it indicates worn threads on windage screw or ramp, or both. Press rear end of ramp down and release, to check spring action of ramp guide plunger.

References

For further information on carbine operation, maintenance, disassembly, and assembly, see FM 23–7 and TM 9–1276. Consult the appropriate current NavOrd allowance list for replacement parts and allowance of spare parts to be carried in stock on the M1 carbine.

U. S. RIFLE, CALIBER .30, M1

You've already studied the caliber .30 rifle M1 (the "Garand") in some detail. Here we'll take up the inspection and gaging that you do on it. Rejected rifles should be returned to the issuing agency for replacement.

Visual Inspection of the M1 rifle (including inspection of barrel, stock, and functioning parts) is very similar to that for the carbine, and will therefore not be repeated here. Similar standards apply. Here are some points in which the M1 is different from the carbine.

1. *Sights.* Operate the rear sight elevation and windage knobs (fig. 13–6A). To verify the setting of the rear sight, set the 100-yard elevating knob graduation opposite the index line on the receiver. With this setting it should be possible to depress the

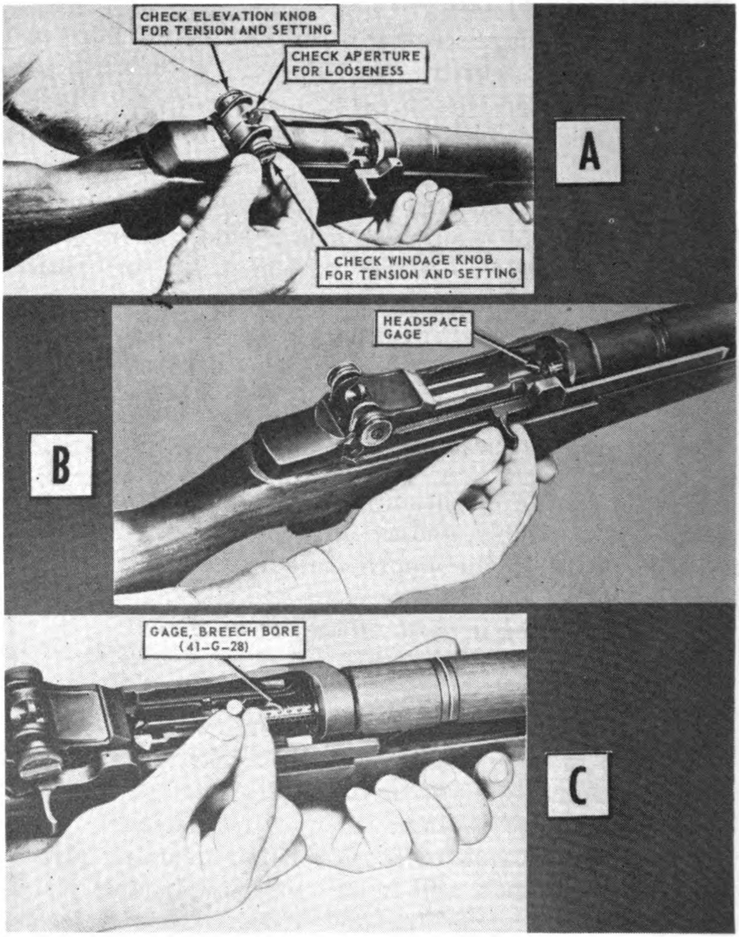

CHECK ELEVATION KNOB FOR TENSION AND SETTING
CHECK APERTURE FOR LOOSENESS
A
CHECK WINDAGE KNOB FOR TENSION AND SETTING
HEADSPACE GAGE
B
GAGE, BREECH BORE (41–G–28)
C

Figure 13–6.—U. S. rifle, caliber .30 M1. Inspection and gaging. A. Points to be inspected on rear sight. B. Headspace gaging.

aperture from one to nine clicks. Check the front sight and the rear sight aperture for looseness. See that the front sight is tightly assembled to the barrel and is not burred or bent. Both sights should have a dull black or gray finish.

2. *Accessories.* See that the oiler, combination tool, and thong case are in the rifle's butt.
3. *Bore.* If the bore is so pitted that the sharpness of the lands is affected, or if pits are large enough to permit the escape of gas around the bullet, reject the weapon. A pit as wide as a land or groove and 3/8 inch long or longer is big enough to cause rejection.

OPERATING INSPECTION. Inspect for live ammunition. Load a clip with eight dummy cartridges into the rifle, and close the bolt fully. Check the operation of the safety. Pull the trigger to check the firing. Then slowly retract the bolt, checking to see that the extractor has fully engaged the cartridge and that the ejector throws the cartridge out of the receiver. Repeat (except for pulling the trigger) for all eight cartridges. The empty clip should be ejected with the last cartridge, and the bolt should remain open.

TRIGGER PULL MEASUREMENT. The method for measuring trigger pull is the same as for the carbine. Trigger pull should be from 5½ to 7½ pounds, and the trigger should respond smoothly to pull, without stopping or gritting.

GAGING. Use headspace gages, as follows:

1. The "minimum" gage is the 1.940-inch gage (Army number 41–G–200–75); the "maximum" gage is the 1.950-inch gage (Army number 41–G–200–130). They look in general much like the carbine's gage shown in figure 13–5B, and are used in the same way fig. 13–6B). The bolt should close fully on the "minimum" gage, and should fail to close on the "maximum" gage.

NOTE: Some older gages have no bevel around the head. These interfere with part of the bolt face, and yield erroneous results. If you have such gages, turn them in for replacement. And some gages have no clearance cut for the ejector. Remove the ejector when measuring headspace, if you have such a gage. It's wise to check your gages well before they're needed, so that older models like these and any that are worn can be replaced. Needless to say, NO gage should EVER be tampered with or modified aboard ship, unless you have an OrdAlt that requires it.

2. If gaging shows excessive headspace, remove the operating rod and take the reading again (with the 1.950-in. gage), rotating the bolt by hand. If headspace is still over 1.950 inch, remove the bolt and replace by a field test bolt. If the headspace checks OK with the field test bolt, it means that the old bolt is worn and requires replacement. If headspace is still excessive, the barrel and receiver assembly is worn and the rifle should be rejected or the barrel and receiver assembly replaced.

CALIBER .38 S&W REVOLVER

It is quite possible that you will run across caliber .38 revolvers in the naval service, particularly in armories at shore activities. In this chapter we shall discuss a common type—the caliber .38 Smith & Wesson Special (fig. 13–7). This weapon is primarily used by personnel assigned to guard duty or police work. A revolver utilizing the caliber .38 special cartridge is considered a more practical close-quarters defense weapon than the bulky caliber .45 pistol.

The caliber .38 S&W revolver is a single-shot, breech-loading hand weapon. The cylinder of the weapon has six chambers and revolves around a central axis. Six shots can be fired without reloading. When the cylinder

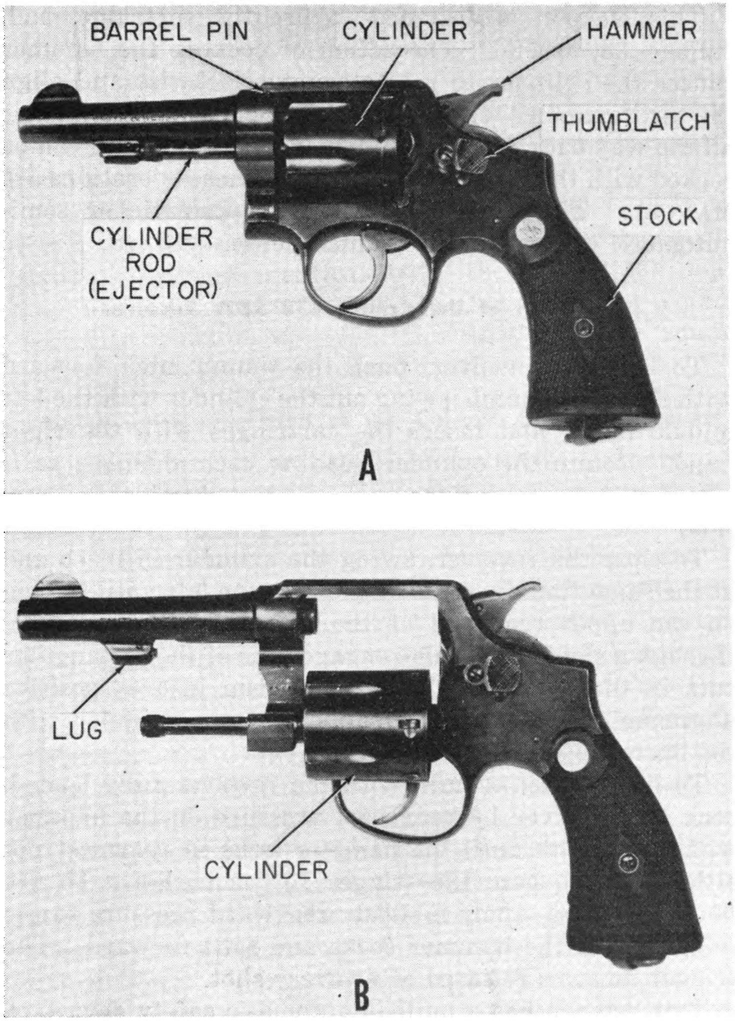


Figure 13–7.—Caliber .38 revolver, S&W special. A. Exterior. B. Cylinder swung out.

is closed, the weapon is ready to fire. Fired cases are extracted manually.

This weapon is designed to fire the cartridge, ball, caliber .38, special. The action of cocking the hammer causes the cylinder to rotate counterclockwise and align the next chamber with the barrel. Squeezing the trigger all the way back cocks the hammer, or the hammer can be cocked with the thumb. Note that all these operations are MANUAL. The revolver is not an automatic or semiautomatic weapon in the technical sense.

Operation of the Caliber .38 S&W Revolver

To load the revolver, push the thumb latch forward with the right thumb, swing out the cylinder with the left middle finger and insert the cartridges with the right hand. Rotate the cylinder, loading each chamber as it comes on top, keeping the weapon pointed in a safe direction.

To close the revolver, swing the cylinder in place and at the same time turn the cylinder to the left until the lug on the upper rear end of the cylinder bolt projecting through a slot in the frame engages one of the rectangular cuts in the cylinder. This mechanism insures positive alignment of one of the chambers of the cylinder with the barrel.

To fire SINGLE ACTION, with the revolver fully loaded, cock the revolver by rearward pressure on the hammer with the thumb until the hammer locks in rearmost position, and squeeze the trigger for each shot. To fire DOUBLE ACTION, apply a steady rearward pressure to the trigger until the hammer cocks and falls forward. The trigger must be released after every shot.

This weapon has a built-in automatic safety device. A projection on the lower end of the hammer resting against the upper surface of the rebound slide prevents the hammer from moving sufficiently far forward to strike the primer, except when the trigger is all the way to the rear.

Thus an accidental blow on the hammer cannot cause the revolver to fire.

Unlike other small-arms weapons, the revolver does not extract and eject an empty case after each shot. Unloading is a separate operation. To unload the revolver, swing out the cylinder, turn the butt downward and depress the ejector rod with the left thumb. This ejects the empty cartridges into your cupped right hand.

One other caliber .38 revolver that is also used in the Navy (but less commonly) is the Colt. This weapon is in structure almost identical with the S&W; the main functional difference is that the Colt's cylinder rotates clockwise when being fired; the S&W cylinder rotates counterclockwise. Both use the same ammunition.

Maintenance Inspection of the Caliber .38 S&W Revolver

All the following are done with the revolver empty:

VISUAL INSPECTION. Check the revolver for general appearance, missing side-plate screws, and defaced markings. Swing the cylinder out and check the bore and the cylinder chambers for rust, corrosion, pitting, and wear. Examine the frame for cracks where the barrel screws into it. Check the stocks for cracks and loose stock screws. See if the front sight is properly aligned and free from burs. The barrel should be firm in the frame. Look for rust where the trigger enters the frame; rust here indicates probable rusting of internal parts, which should then be examined closely.

OPERATING INSPECTION. Pull the hammer back slowly, and note whether it moves smoothly and the cylinder rotates as it should. If the cylinder bolt fails to engage the recess in the cylinder, the cylinder is not properly aligned with the bore. Repeat the test operation using the trigger, and observe closely the functioning of the hammer and cylinder. Perform also the following safety tests:

1. With cylinder closed, cock the hammer (fig. 13–8A). Holding the hammer back with the thumb, press the trigger, and let the hammer move forward about ¼

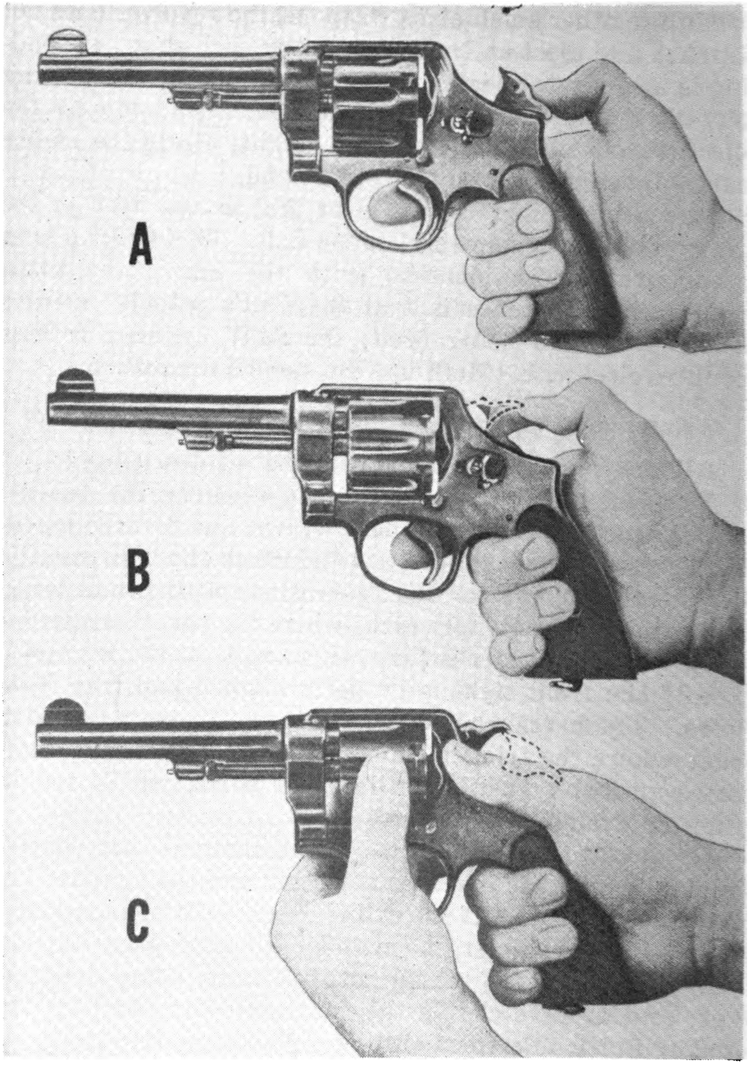


Figure 13–8.—Caliber .38 revolver S&W special. Safety tests.

inch (fig. 13–8B). Release the trigger; then release the hammer and let it fly forward. If the firing pin projects through the hole in the frame, the weapon is defective and should be rejected.

2. With hammer down, try to rotate the cylinder (fig. 13–8C). Repeat with hammer cocked. If more than 1/64 inch rotation is possible in either case, the weapon is defective and should be rejected.

   NOTE: The cylinder rotates freely when the hammer is about one-fourth back from down position.

TRIGGER PULL. Measure trigger pull required to cause the hammer to fall in single action—that is, with the hammer cocked. The weights to be used are 5 and 6½ pounds.

PISTOL, CALIBER .45, M1911A1

You have already studied the caliber .45 pistol in some detail. In this section we shall, as with other small-arms weapons, discuss maintenance inspection.

VISUAL INSPECTION. First, check to be sure there is no live ammunition in the pistol. Inspect for general condition, then check the details. Look for burs, dents, and rough spots on the sights, slide, and receiver. Retract the slide and inspect the chamber and bore. Look for evidence of corrosion here and on the surfaces that are exposed to powder gases. Check for worn stock checkering, missing stock screws, and splitting of the stocks.

OPERATING INSPECTION AND SAFETY TESTS. Put the weapon through its paces with dummy ammunition, retracting the slide by hand to check ejection. Then perform the following safety tests with the pistol unloaded:

1. *Safety lock test.* (See fig. 13–9A.) Cock the hammer and press the safety lock upward into safe position. Grasp the stock so that the grip safety is depressed and squeeze the trigger tightly three or four times. If the hammer falls, the safety lock is not safe and must be replaced.

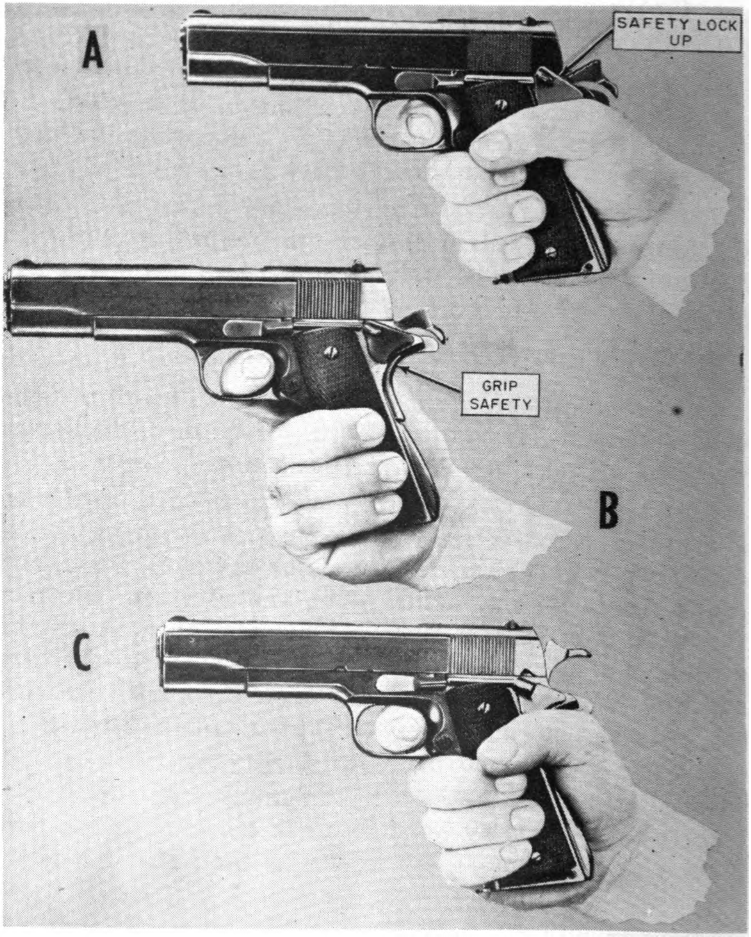


Figure 13–9.—Pistol, caliber .45, M1911A1. Safety tests.

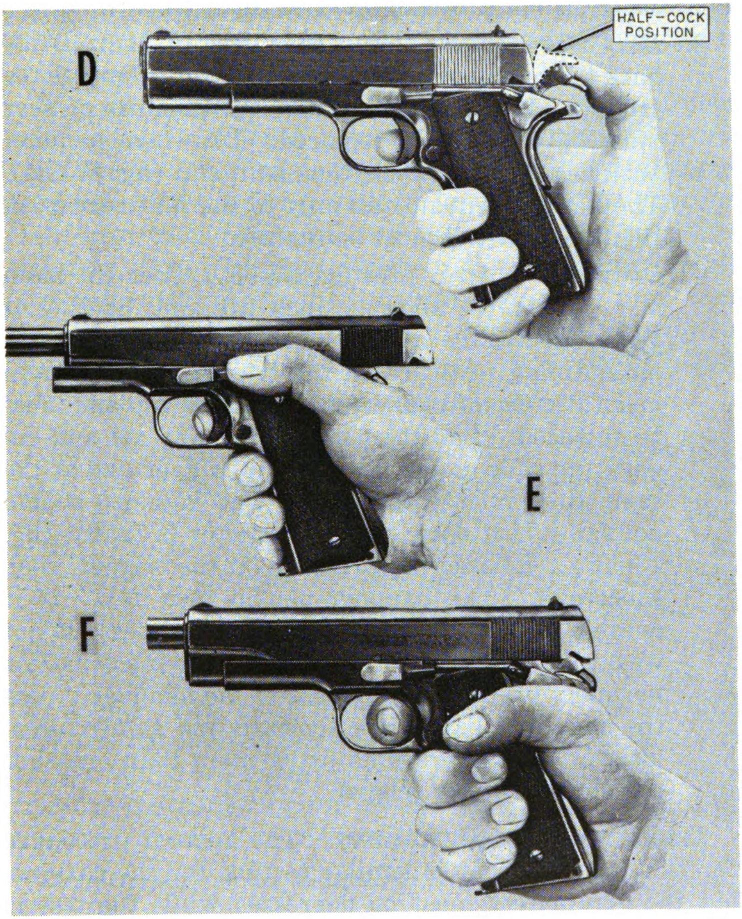


Figure 13–9.—Continued.

2. *Grip safety test.* (See fig. 13–9B.) Cock the hammer and, without depressing the grip safety, point the pistol downward and squeeze the trigger three or four times. If the hammer falls, or the grip safety is depressed by its own weight, the grip safety is not safe and must be replaced.
3. *Half-cock position test.* (See fig. 13–9C.) Draw back the hammer to half-cock position. Squeeze the trigger. If the hammer falls, the hammer or sear must be replaced or repaired. Draw the hammer back nearly to full cock, then let it slip (fig. 13–9D). The hammer should fall only to the half-cock position, otherwise it must be replaced.
4. *Disconnector test.* (See fig. 13–9E.) Cock the hammer. Push the slide ¼ inch aft and, holding it there, squeeze the trigger. Let the slide go forward, maintaining pressure on the trigger. If the hammer falls, the disconnector is worn on top and must be replaced. Pull the slide all the way aft and engage the slide stop. Squeeze the trigger and at the same time release the slide. The hammer should not fall. If it does, the disconnector is faulty (fig. 13–9F). Release the pressure on the trigger, then squeeze it. The hammer should then fall. If it doesn't, check the sear spring for weakness; if not weak, the disconnector is faulty. The disconnector normally prevents the release of the hammer unless the slide and barrel are forward and safely interlocked. It also prevents firing more than one shot per squeeze of the trigger.

TRIGGER PULL MEASUREMENT. The general procedure for this measurement is similar to that for the carbine, but the grip safety must be depressed while the test is performed. Use a magazine of dummy ammunition when testing. Trigger pull weights should be 5 and 6½ pounds. After this measurement, pull the trigger several times to determine if there is too much creep.

SHOTGUNS

As you remember from the preceding course in this series, the shotguns used by the armed forces are not specialized military weapons, but are civilian models procured for certain uses like guard work and skeet shooting. The armed forces use a variety of makes and models of shotguns.

You are already familiar with the main types of shotgun and with shotgun nomenclature. This section will take up the functioning, construction, and maintenance inspection of the two standard issue shotguns that you will most likely encounter in the Fleet—the two Winchesters, M97 (hammer type) and M12 (hammerless). For information on other shotguns that you may come across, see the Army technical manuals TM 9–285 and TM 9–1285. For parts lists on shotguns, see Army SNL B–9.

WINCHESTER SHOTGUN M97

Now, let's go into a little detail on the Winchester 12-gage M97, used in the Navy for guard work. (See fig. 13–11A.) This is a manually operated repeater, slide-action, hammer-type shotgun with full-cylinder plain 20-inch barrel. (Grades for skeet and trap use are available with other barrels.) It is available in either takedown or solid-frame construction, and normally comes equipped as a riot type with bayonet, hand guard, and bayonet attachment. For positive identification of this shotgun, look for the maker's name, gage, model, and barrel boring at the top of the barrel near the breech end. The serial number is stamped on the lower face, forward end, of the receiver, and also on the barrel breech end, lower face.

Characteristics of the Winchester Shotgun M97 (Riot Type)

Length (in. overall) with 20-in. barrel (approx.)	39
Weight without bayonet (lb)	7.2
Maximum muzzle velocity, avg. over 40-yd range (fps)	1,070
Approximate chamber pressure (psi)	11,000
Length of barrel, riot type only (in.)	20

Approximate maximum range (#00 buckshot) (yd)	748
Patterns (percentage) of shot in a 30-in. diameter circle at 40 yds. (#00 buckshot)	33⅓
Bore	12 gage
Trigger pull (lb)	4 to 8
Shell capacity	5 in magazine, 1 in chamber

Functioning of the Winchester M97

The heart of the Winchester M97's mechanism is shown in figure 13–10. The important units are the BREECH BOLT, the CARRIER, the ACTION SLIDE BAR, and the ACTION SLIDE HOOK, which are housed in the RECEIVER.

The CARRIER (fig. 13–10C) is an irregularly shaped steel piece pivoted on a carrier pin running horizontally through its after end. Its forward end swings vertically as the carrier is cammed up and down. The carrier contains the hammer, sear, and action slide lock. Note the concave (hollowed-out) part of the carrier. A similar concavity is in the top side of the carrier.

The rectangular BREECH BOLT contains the firing pin, firing-pin lock, and extractors. The boxlike part of the bolt below the bolt's forward end contains the action slide hook screw hole.

Now look at figure 13–10 to see how the mechanism works. Part A shows the position of the mechanism with the action slide handle pulled aft. The action slide bar, which is connected to the handle, has on its extreme after end a lug that fits into the carrier's camming groove, camming the carrier downward. Movement of the action slide handle also actuates a linkage (not shown) to draw a shell from the magazine and deposit it on the upper concave surface of the carrier.

In this position, the action slide bar's after end engages the action slide hook, which is pinned to the breech bolt, thus pulling the bolt to rearward position, opening the breech, and camming the hammer back to cocked position.

Figure 13–10B shows the mechanism with the action

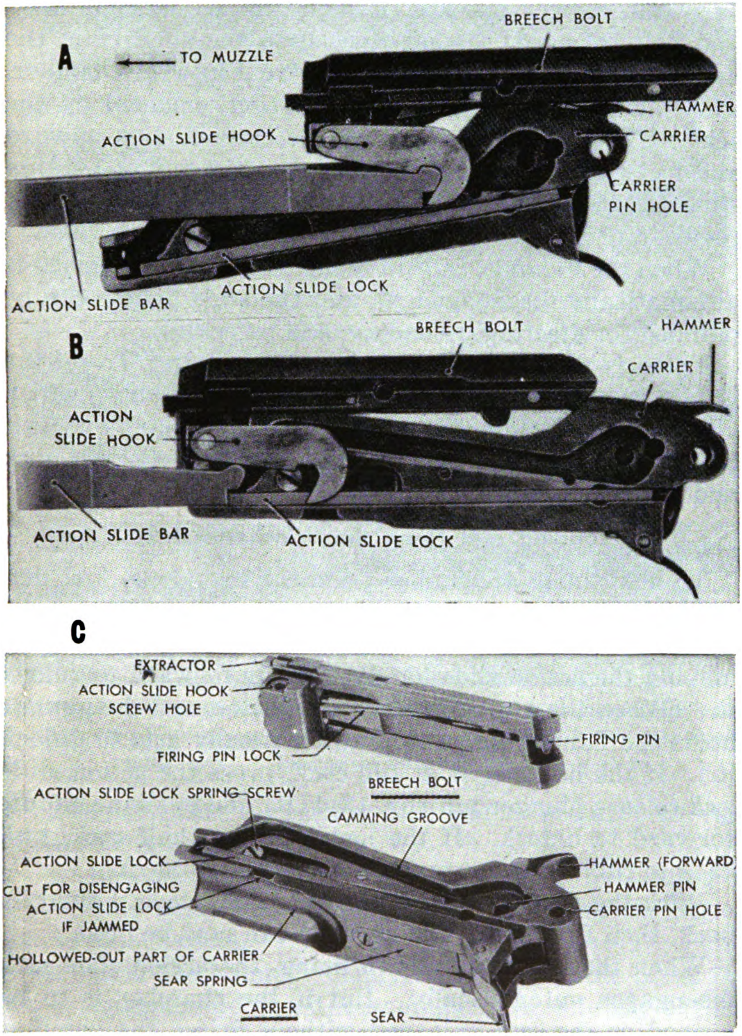


Figure 13–10.—Winchester 12-gage shotgun M97. Breech bolt, carrier, and slide bar groups. A. Position with action slide handle retracted. B. Position with action slide handle forward. C. Detail view of breech bolt and carrier.

slide handle pushed forward. As the action slide bar cams the carrier upward, it pulls the action slide hook and bolt forward, so that they strip the shell from the upper surface of the carrier and drive it into the chamber. The hammer is left in cocked position, engaged by the sear. The action slide lock on the carrier slips upward and locks the action slide bar so that the bar and action slide handle cannot be moved back. The shotgun is now ready to fire.

When the hammer falls in firing, the action slide lock is automatically disengaged, so that the slide handle can be pumped for ejecting, reloading, and recocking.

There is no trigger safety on this shotgun. To set the gun at SAFE, you move the hammer to HALF COCK, which also locks the trigger and the action slide handle. Half cock is the hammer position midway between full-cock and hammer-released positions.

Loading and Firing the Winchester M97

To load the gun chamber from the magazine, first disengage the action slide lock so that the action slide handle can be operated. If the gun has just been fired, do this by moving the action slide handle slightly forward to unlock it. (When the gun is fired as a repeater, and the gunner holds the handle, gun recoil automatically acts to unlock it.) If the hammer is at full cock, press the action slide lock release plunger pin (fig. 13–11B) and push the handle forward to unlock. If the hammer is at half cock, pull back to full cock, and proceed as above to unlock.

With the action slide handle unlocked, move it smartly back, then forward. The shotgun can now be fired.

When the hammer falls in firing, the action slide lock disengages automatically. But if the chamber is to be opened or the gun unloaded without firing, the hammer must be set at SAFE, and the slide-lock release plunger (which disengages the slide lock) depressed. Then the action slide handle can be pulled back to eject the shell in the chamber (fig. 13–11B).

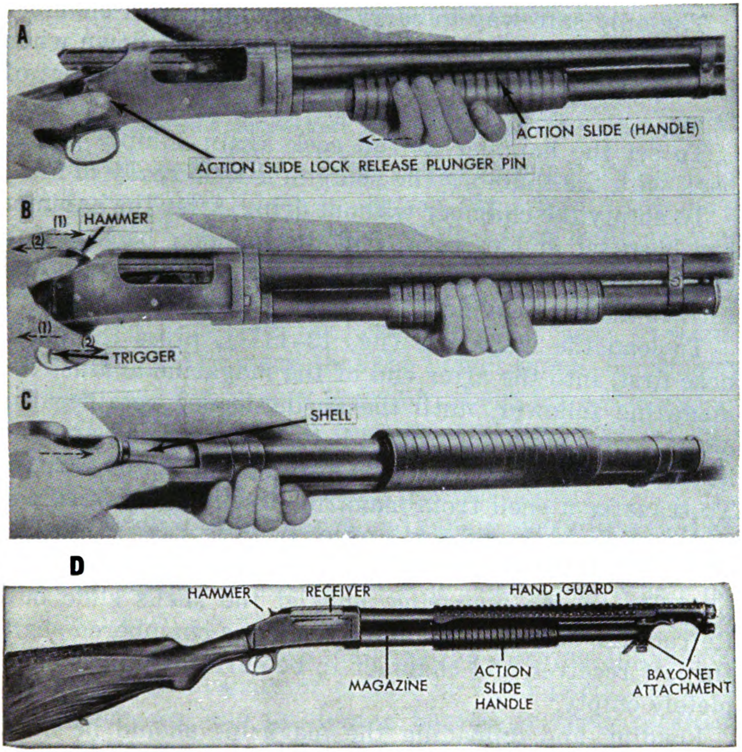


Figure 13–11.—Winchester shotgun M97, riot type. A. Depressing the action slide lock release plunger pin, and retracting action slide. B. Setting hammer at half cock. C. Loading the magazine. D. General view.

The procedure for setting the hammer at half cock (fig. 13–11C) is as follows:

1. Set the hammer at full cock, either by pulling it back with your thumb or by operating the action slide handle.
2. Hold the hammer firmly with the thumb, press the trigger, and ease the hammer down slightly beyond half-cock position. Release pressure on the trigger as soon as the hammer is released from full cock.
3. Pull the hammer back until it clicks into position at half cock.

The only safe way to carry the shotgun with chamber loaded is at half cock. NEVER let the hammer down when there is a live shell in the chamber, except in the act of firing.

To set the hammer at full cock again, simply pull it back with the thumb. The shotgun is then ready to fire.

To empty the chamber without firing, after the hammer has been set at half cock, pull the hammer back to full cock, press the action slide lock release plunger pin, and retract the action slide handle.

To load the magazine (fig. 13–11D), press the shell, nose first, into the after end of the magazine against the magazine follower, until the spring-loaded retainers or SHELL STOPS snap out behind it to hold it. Load another in the same way, and continue loading until all five are in. To transfer a shell from magazine to chamber, work the slide handle back and forth once.

To unload the magazine, press in the two shell-stop plungers on the magazine, and let the shells slide out. Retract the action slide handle to eject a chambered shell. Inspect receiver and chamber to be sure the gun is completely empty.

Loading and unloading the magazine should be done only with the hammer at half cock.

To load the chamber only, with magazine empty, retract the action slide handle; place the shell directly in the chamber through the ejection opening in the receiver; close and lock the bolt by pushing the slide handle forward again; and set the hammer at half cock.

SAFETY PRECAUTIONS WHEN LOADING, UNLOADING, AND FIRING. In addition to the general safety precautions applicable to small arms, note the following specific precautions for this weapon.

1. Keep the hammer at half cock (SAFE) when the gun is loaded unless you are about to fire.
2. Never let the hammer down on a loaded chamber except in firing.

3. When operating the action slide handle:
   a. Keep fingers OUTSIDE the trigger guard.
   b. Keep the gun pointed in a safe direction.

Maintenance Inspection of Winchester M97 Shotguns

VISUAL INSPECTION AND ELEMENTARY REPAIRS. The parts most important to inspect visually are the barrel and bore. Look for looseness of the barrel in the receiver, for rust, pits, leading, cracks and bulges. If it's loose, tighten it. Remove leading (dull gray streaks) and rust (dark patches) from the bore. Bulges, cracks, or serious rust and pitting mean that the barrel should be replaced. Bulges may not be easy to detect. Look for a shadowy depression or dark ring in the bore, and for a raised ring or distortion on the barrel outer surface. And check for loose wood screws and cracks in wood parts.

The simple maintenance and repair operations that will take care of many defects revealed by visual inspection can be performed easily by most small-arms repair personnel, even by those not necessarily shotgun experts. Such operations (other than routine cleaning and lubrication) include repair of cracks in wood parts, reseating wood screws, and tightening barrels in their receivers, and they apply both to M97 and M12 Winchester shotguns.

Rust or corrosion outside the bore can, if it's light, be removed with an oily rag or a rag moistened with rifle bore cleaner. More stubborn deposits may require careful rubbing with crocus cloth or even with fine steel wool. Be careful not to scratch metal surfaces any more than necessary. To remove corrosion or leading in the bore, push a wad of fine steel wool straight through it several times. Don't scrub or turn the wad in the bore.

When wood screws strip out, you can reset them by boring out, plugging, reboring the stripped hole, and reseating the screw. You can often check small wood cracks by boring a small hole just ahead of the crack and plugging it with shellac or plastic wood (NOT with a wooden plug). But if the crack is extensive, replace the part.

In takedown type Winchesters, you can tighten a loose barrel and magazine where they mate with the receiver as follows:

1. Take down the gun. Remove lock screw from receiver extension. Slide back and disengage adjusting sleeve lock from adjusting sleeve (fig. 13–12).

2. Turn sleeve back one notch, engage lock with sleeve, and replace lock screw.

3. If barrel is still loose when reassembled, repeat until tight.

FUNCTIONING INSPECTION. This is done with the gun completely assembled. Be sure it's not loaded. Use dummy shells. If none are available, you can use fired shells if you bend inward the prongs at the open end so that the length of the shell is about the same as that of a

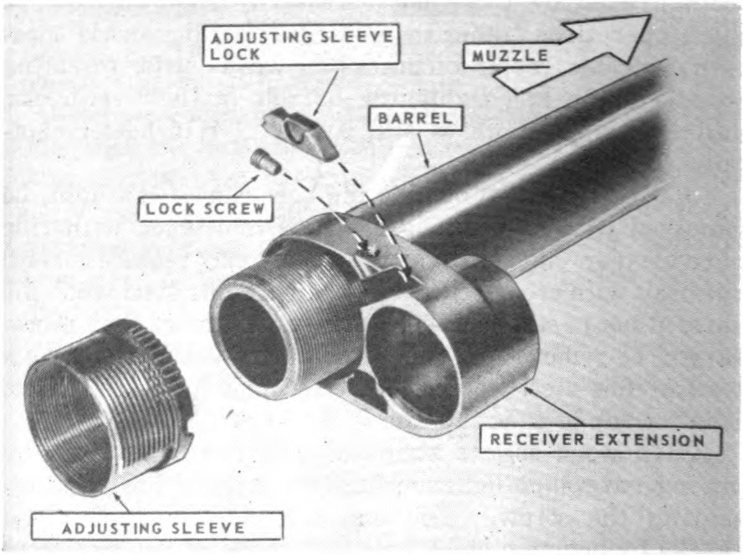


Figure 13–12.—Winchester shotgun M97. Barrel adjusting sleeve (disassembled).

live shell. NEVER use live shells for testing. Here is the testing procedure:

1. With breech bolt locked, and hammer at full cock, press in the action slide lock release plunger pin. Push action slide handle forward slightly and pull smartly and fully to the rear; then push smartly and fully forward. Repeat several times to test smoothness of action. Do not slam the mechanism.
2. Let hammer down to half cock, press release plunger pin, and try to retract action slide as above. It should not be possible to do it.
3. Retract hammer slightly to clear sear, retract trigger, and ease hammer down to fired position. Repeat test as in 1. above. The action slide should retract.
4. Retract slide as in 1. above, release plunger pin, and push slide smartly and fully forward to lock breech bolt. Then try to retract action slide. This should be impossible with hammer at full cock until action slide lock is disengaged.
5. With breech bolt locked and hammer at full cock, pull trigger to test firing mechanism. Set hammer at half cock and try to pull trigger. Since at half cock the firing mechanism is in SAFE position, pulling the trigger should NOT fire the gun.
6. With hammer at full cock, close but do not lock breech bolt. Then try to fire. The gun should not fire until the breech bolt is locked.
7. Put two dummy or fired shells in the magazine. Work the action to test gun for feeding, loading, extraction, and ejection. The second shell should not leave the magazine until after the carrier drops as the first shell is ejected.

   NOTE: Fired shells may not work through the action as easily as live or dummy shells. Allow for this when testing.

8. Test for trigger pull, using the same general method as that described for carbines. Trigger pull should be between 5 and 8 pounds with the pressure to be applied about $1/4$ inch from the lower end of the trigger and parallel with the barrel. When testing, the gun must be unloaded, action locked, and hammer at full cock.

The functioning inspection is extremely important. If a bolt fails to lock properly or a slide lock or similar part fails to function, the breech may blow open when the gun is fired, with a risk of serious injury to the firer. No gun is acceptable unless it passes ALL phases of functioning inspection. If repair parts, proper tools, and qualified personnel are aboard, defective weapons should be repaired. (See Army TM's 9–285 and 9–1285 for information on troubleshooting and repair work.) Otherwise defective shotguns should be turned in to the issuing activity (or Naval Supply Center) for replacement.

WINCHESTER SHOTGUN M12

The Winchester shotgun M12 is a manually operated "hammerless" repeater of the slide-action type generally issued in 12-gage (but you'll sometimes find 16-gage specimens). The barrel, magazine, and action slide group are similar in design to (though not interchangeable with) those of the M97, but the receiver and operating mechanism differ. The riot type gun (the one most often issued in the Navy) is usually furnished with a 20-inch plain full-cylinder bore barrel, and may be equipped with a bayonet attachment and hand guard at the barrel's muzzle end. Figure 13–13A shows a sporting model. Identification marks are located in the same places as on the M97.

Loading and Firing the M12 Winchester Shotgun

In general outline, the operations required for loading and firing the M12 Winchester are similar to those for the M97. Here are the main differences (concerned mostly

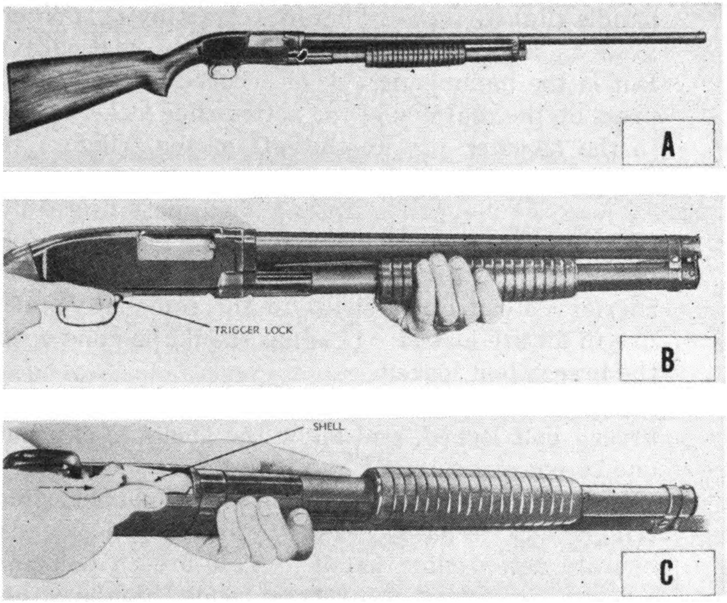


Figure 13–13.—Winchester shotgun M12. A. General view. B. Trigger (safety) lock. C. Loading the magazine.

with the concealed hammer of the "hammerless" M12, and the slightly different loading arrangements):

1. There is no hammer half-cock position. The shotgun trigger safety is a lock button in the trigger guard bow (fig. 13–13B). In SAFE position (pushed to the right) it blocks trigger movement rearward. Pushing it to the left (to FIRE position) reveals a red band and unlocks the trigger. If there is a shell in the chamber, the safety should be at SAFE unless the gun is to be fired. Safety precautions when firing are similar to those for the M97. Keep fingers out of the trigger bow when operating the action slide handle, and release the trigger completely between shots.
2. As with the M97, the gunner disengages the action slide lock after each shot by moving the action slide

handle slightly forward before retracting it. (When fired as a repeater, this happens automatically.) But if the hammer is already cocked he must first press up the rear end of the action slide lock (visible in the receiver just to the left of the trigger) to disengage it.

3. To load the magazine, press a shell, nose first, into the rear of the magazine against the magazine follower until it slips in front of, and is retained by the carrier. Load other shells in the same way until five in all are loaded. Loading should be done with the breech bolt locked.
4. To unload magazine, press up the carrier with breech bolt locked, and allow the shells to slip out one by one.
5. To transfer a shell from magazine to chamber, slide trigger lock to SAFE, release action slide lock, and operate action slide handle. Test breech bolt for locking by trying to retract slide handle. (It should not retract.) Leave trigger lock on SAFE unless you intend to fire at once.
6. To unload the gun, slide trigger lock to SAFE, and unload magazine. Disengage slide lock and retract slide handle to extract and eject shell in chamber. Inspect magazine and chamber to be sure gun is empty.
7. Loading the chamber without loading the magazine is done exactly as with the M97, except that you set the M12 trigger safety button at SAFE.

Functioning of the Winchester M12

As with the M97, the mechanism of the M12 is operated when you work the action slide handle back, then forward. A cam lug on the action slide bar after end engages a camming aperture in the left side of the breech bolt. As the slide moves aft, the breech bolt rear end is cammed down from in front of the locking shoulder in the top of the receiver and the bolt moved to the rear. As the slide

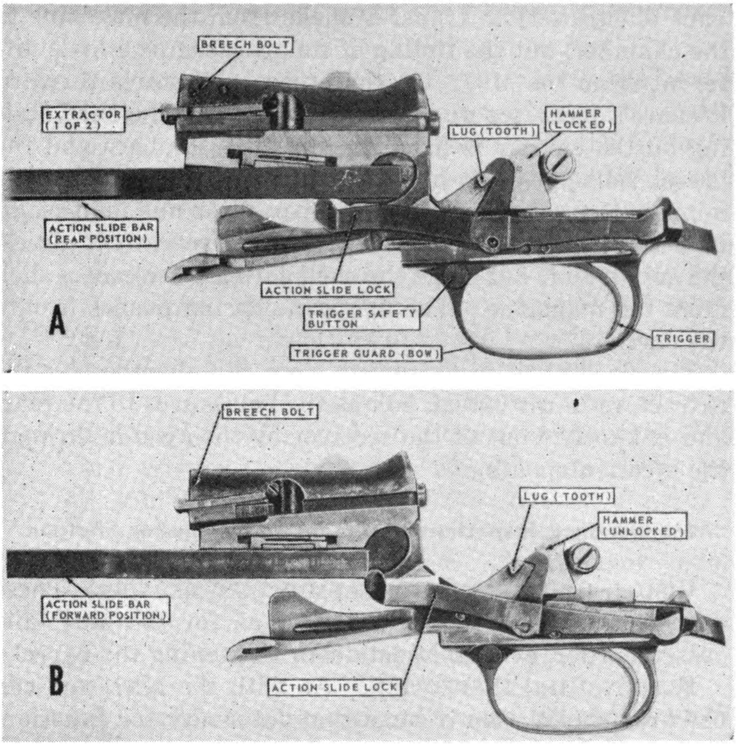


Figure 13–14.—Winchester shotgun M12. Breech bolt and action slide bar groups. A. Action slide bar disengaged; hammer locked. B. Action slide lock engaged; hammer unlocked.

moves forward, the breech bolt also moves forward and its rear end is cammed up in front of the locking shoulder.

As the breech bolt moves aft it cams back the hammer which is caught and held by a hook (fig. 13–14A) on the action slide lock. As the breech bolt reaches forward position, the action slide lock, which has been held down by the action slide bar, is released and springs up behind the action slide bar to block its rearward movement (fig. 13–14B). At the same time, the lock releases the hammer, which is then held by the sear.

The M12 Winchester, much like the M97, uses a carrier (not illustrated) to transfer shells from the magazine to the chamber, but the timing of its operation is a little different from the M97. As the breech bolt starts forward it cams the carrier up and down rapidly. The shell resting on the carrier is lifted in line with the bore and the breech bolt pushes it into the chamber. The carrier has immediately returned to the lower position and is in readiness to receive another shell. As the breech bolt closes, the action slide bar cams the shell cut-off to release a shell from the magazine. The magazine spring pushes it onto the carrier.

The fired shell is extracted from the chamber by the extractors in the breech bolt as the bolt moves to the rear, and is knocked out of the receiver by the ejector through the ejection opening.

Maintenance Inspection of the M12 Winchester Shotgun

VISUAL INSPECTION AND ELEMENTARY REPAIRS. These aspects are the same for the M12 as for the M97, discussed earlier, even unto details of tightening the barrel.

FUNCTIONING INSPECTION. As with the M97, you can use fired shells, even if somewhat deformed, for functioning tests if you turn in the open ends. But make allowance for these deformations when judging smoothness of action. Be sure the gun has no live ammunition in it when performing these tests. Here are the testing operations:

1. With breech bolt locked and hammer cocked, press upward on the action slide lock rear end. Push action slide handle forward slightly, pull smartly and fully to the rear, then push smartly and fully forward. Do this several times to test smoothness of action. But don't slam the mechanism.
2. Retract action slide as in 1. above, release pressure on rear of action slide lock, and push slide smartly forward to lock breech bolt, then attempt to retract the action slide. The action slide should not retract.

3. Pull the trigger to make the hammer fall. Try to retract the action slide. It should retract.
4. Retract it fully, then push forward until the breech bolt is fully forward, but not raised to the locked position. Pull the trigger to release the hammer. The hammer should not descend until the breech bolt is fully locked.
5. Place two more dummy or fired shells in the magazine and work the action to test for feeding, loading, extraction, and ejection. The second shell should not leave the magazine until the breech bolt is locking behind the first shell in the chamber.
6. With breech bolt locked and hammer cocked, push the trigger safety lock all the way to the right. Pull the trigger. The trigger should not retract nor should the hammer descend.
7. Push trigger lock all the way left, so that red band shows, and pull the trigger. The trigger should retract and release the hammer.

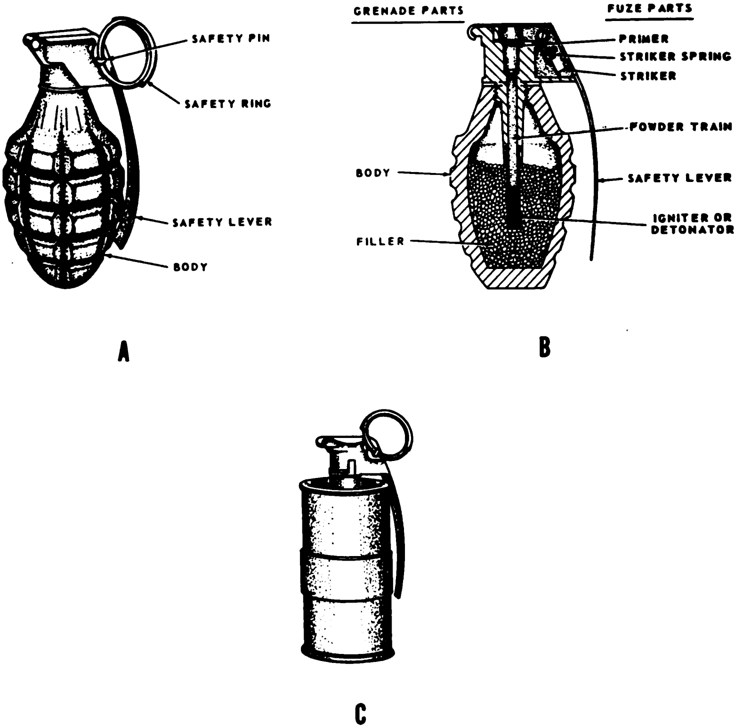
HAND GRENADES

A hand grenade is a small do-it-yourself bomb, with the user's arm providing the motive power to get it to the target. (There are also rifle grenades, which through use of adapters and special blank cartridges can be fired by M1 rifles. These are not so widely used aboard ship as part of the landing party armament, so we won't take them up here. For information on them, see the *Landing Party Manual* and the *Guidebook for Marines.*) Hand grenades may be filled with explosives, explosives and chemicals, or (for practice purposes) may be empty or contain inert filler. Following are the main types of hand grenades used in training and combat:

FRAGMENTATION GRENADES. (See fig. 13–15.) These contain an explosive charge which shatters the body into fast-flying fragments when detonated.

OFFENSIVE GRENADE. (See fig. 13–15.) These have a paper body enclosing a high-explosive filler. They are designed for blast effect and produce little fragmentation.

Chemical grenades contain chemical agents. Typical chemical grenades produce smoke for signaling or screening, or gas for poisonous or irritating effects, or act as incendiaries. They look like offensive grenades, but have different identifying lettering.



Courtesy of Leatherneck Association, Inc.

Figure 13–15.—Hand grenades. A. Fragmentation type (exterior). B. Fragmentation type (cross section). C. Offensive grenade.

Practice grenades have a body and fuze like the fragmentation grenade, but only a small powder charge. They are designed to familiarize the users with fuze action during grenade practice. The grenade body does not burst.

TRAINING GRENADES have a removable safety pin and pull ring but no filler or fuze. They resemble fragmentation grenades externally.

How to Use Hand Grenades

The technique of using hand grenades with maximum effectiveness requires practice to master, and instruction in grenade-throwing is best given by experienced personnel like qualified Marines. If you're assigned to instruct in the use of grenades, use the methods and observe the safety precautions described below, and check with other sources like *Handbook for Marines* and the Army's FM 23–30.

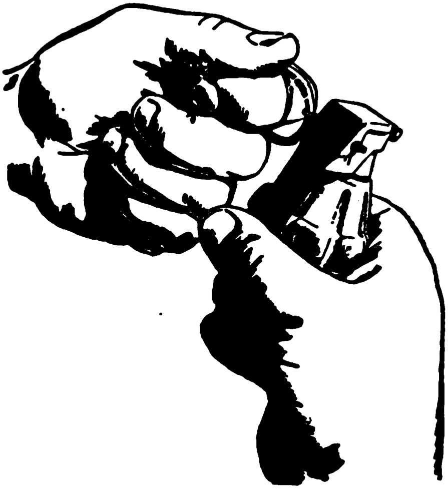


Figure 13–16.—Holding the grenade in preparation for throwing.

Grenades have two safety devices—the safety pin with ring attached, and the safety lever. For the grenade to function, both must be operated. Before you throw the grenade, hold it as in figure 13–16, ready to pull the pin.

But do NOT remove the pin until just before you throw, and keep your grip on the safety lever until you are actually throwing the grenade. Pull the pin with a twist and without changing the grip of the throwing hand.

The throwing technique depends on the individual. Most men throw it like a baseball. Use whatever method gives you the best range and accuracy. Release it with a snapping motion of the wrist and let it roll off your fingers to give it a spinning motion. Then DROP FLAT or crouch behind shelter. The safety lever falls off, and the striker initiates the powder train (fig. 13–15B) as soon as the safety lever has released it. The bursting charge functions in 4 to 5 seconds.

Stowage and Maintenance of Hand Grenades

Hand grenades are really ammunition, just as bombs are, and should be treated like ammunition. All of them contain a sensitive initiating compound like mercury fulminate, as well as black powder. Offensive grenades contain a high explosive (generally TNT). Chemical grenades contain chemical filler, in addition to the black powder or other burster. Stow them in dry, cool locations. In general, you can treat them much as you would 40-mm ammunition, except that grenades contain no smokeless powder.

Safety Precautions

1. Don't pull the pin until you are ready to throw.
2. Don't release the safety lever before throwing.
3. If through some accident you pull the pin and release the lever before throwing, DON'T TRY TO PUT THEM BACK. And don't try to pick the grenade up. Just scram, and get behind substantial cover. Unless you're behind cover, don't consider yourself safe from fragments (of a fragmentation grenade) unless you're at least 40 yards from the point of detonation.

4. Don't try to recover or tamper with a live grenade that fails to fire. Duds may be recovered and destroyed only by trained personnel as prescribed by existing regulations.
5. Don't try to take any grenade apart.
6. In throwing grenades, use care to avoid hitting intervening obstacles such as walls, trees, and vines.
7. When live fragmentation grenades are thrown, take the following precautions:
    a. All personnel within a radius of 250 yards must wear steel helmets.
    b. Fragmentation grenades must be thrown to obtain ground bursts.

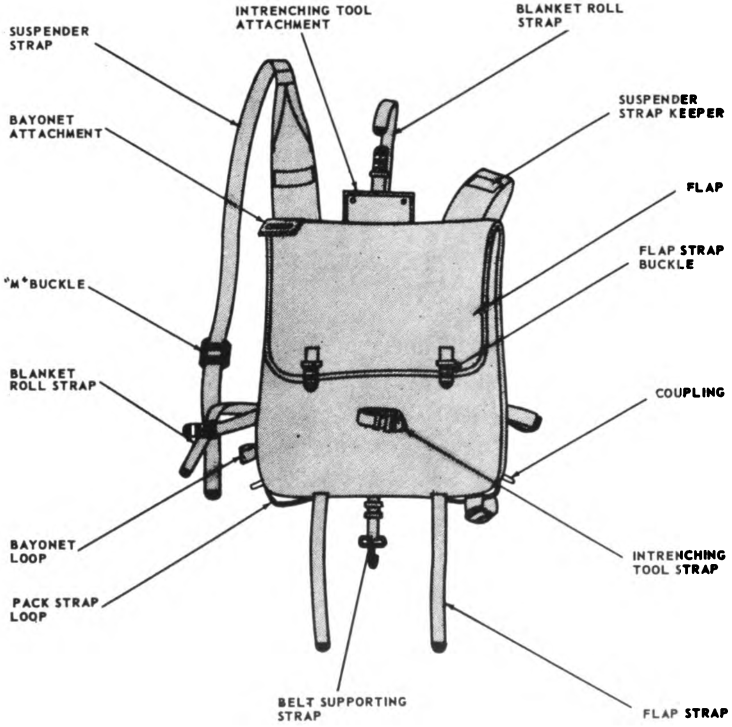


Figure 13–17.—Marine Corps pack M1941. Haversack.

c. Grenades must be thrown so that they explode at least 40 yards from anybody (other than the target) not protected by cover.

WORKING WITH LANDING PARTY GEAR

Your qualifications require that you be able to instruct in the use of landing party (infantry) equipment. This includes, besides the weapons discussed earlier, packs, gas masks, intrenching gear, and tents. You already know what these are. In this section we'll go over their uses. For more detailed instructions and more illustrative material than can be included here, see the *Landing Party Manual.* You'll also find detailed discussion on this subject in the *Handbook for Marines.*

Types of Pack Assemblies Made with Pack M1941

The three main components of the Marine Corps M1941 pack, which is prescribed for landing party use, are the haversack (fig. 13–17), the knapsack, (not illustrated here), and the belt suspenders (fig. 13–18). Using these

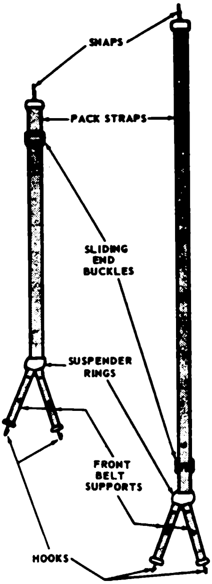


Figure 13–18.—Marine Corps pack M1941. Belt suspenders.

components in combination, along with short and long blanket rolls, you can make up a number of different types of pack assemblies. The most usual ones, and the combinations they require, are listed below:

Assembly	*Components Used*
Light marching pack, (fig. 13–20A).	Haversack and (optional) cartridge belt.
Marching pack, (fig. 13–21).	Haversack, belt suspenders, and cartridge belt.
Field marching pack, (fig. 13–20B).	Marching pack plus short blanket roll.
Transport pack, (fig. 13–20C).	Marching pack plus knapsack.
Field transport pack, (fig. 13–20D).	Transport pack plus long blanket roll.
Knapsack pack.	Knapsack, belt, and belt suspenders.

Along with these packs you carry, as prescribed, rations, toilet articles, mess gear, clothing, intrenching tools, and other equipment. Figure 13–22 shows such typical additional equipment as the rifle and gas mask worn with the marching pack.

The commonest of these pack assemblies are the marching pack and light marching pack, the former of which can be combined with the short blanket roll to make up the field marching pack. We'll describe how to make up these pack assemblies (which don't use the knapsack) and the blanket rolls. For details on the other pack assemblies referred to here, see the *Landing Party Manual.*

Making up Pack Assemblies

BLANKET ROLLS. Both the long and the short rolls are made with the same components, except that the long roll may contain two blankets instead of one. Besides blankets, the components are a tent shelter half which goes on the outside, a shelter tent guy line, five tent pins, and a tent pole.

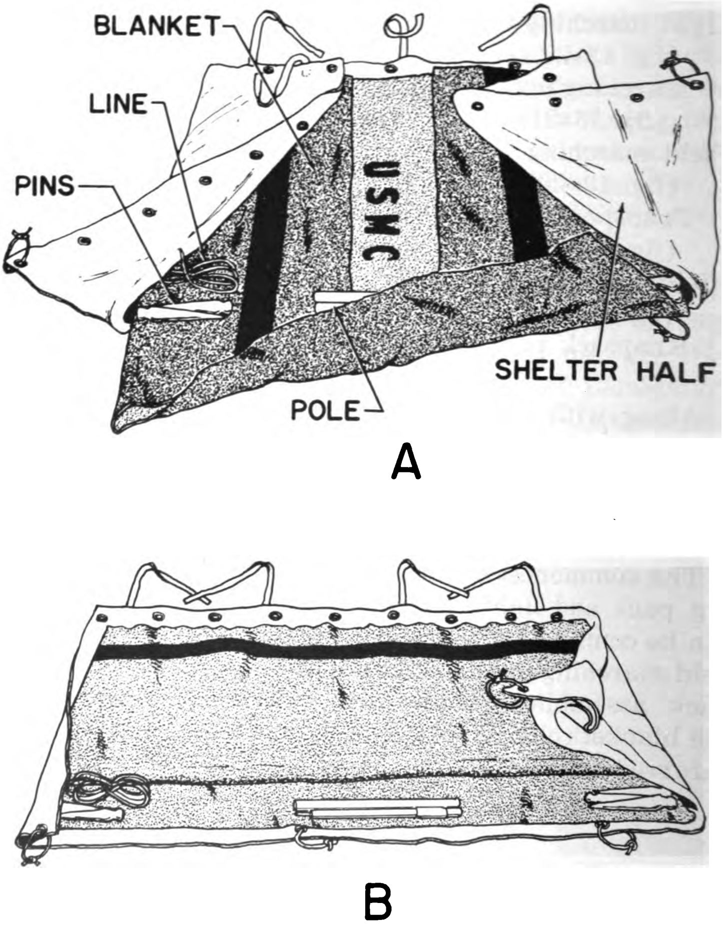


Figure 13–19.—Blanket rolls. A. Short. B. Long.

To make up the short blanket roll, fold the blanket and place the poles, pins, and guy lines as in figure 13–19A. Fold the blanket so that it's as wide as the length of the extended tent pole. Roll the assembly from the bottom edge of the tent, and secure.

To assemble the long blanket roll, lay out the shelter half, fold the blanket in half, lay the pole, pins, and guy line as in figure 13–19B, roll from the bottom edge, and secure. It's a good idea for two men to work together on the long roll.

LIGHT MARCHING PACK. To assemble this pack:

1. Pass the free ends of the haversack suspender straps up and through the first slot from the top of the M buckles and down and through the second slot. (The top of the M buckle is the part with the hole in it.) The top of the M buckle should face the top of the pack.
2. Pass the free ends of the haversack suspender straps through the pack strap loops from front to rear. (The front of the pack is the part that rests on the man's back.) Before you do this, give the straps a half turn outboard to make them lie better.
3. Pass the free ends of the haversack suspender straps up and through the third slot from the top of the M buckles, and down and through the fourth slot. Adjust the pack to the wearer by adjusting the M buckles.

MARCHING PACK. This pack assembly, which is used as a combat pack and on exercises not involving bivouac, is made up as follows:

1. Pass the free end of the haversack suspender strap up and through the top slot of the M buckle (whose top is toward the haversack top) and down through the fourth slot.
2. Couple the haversack suspenders to the belt suspenders by passing the free end of the haversack suspender strap through the belt suspender ring,

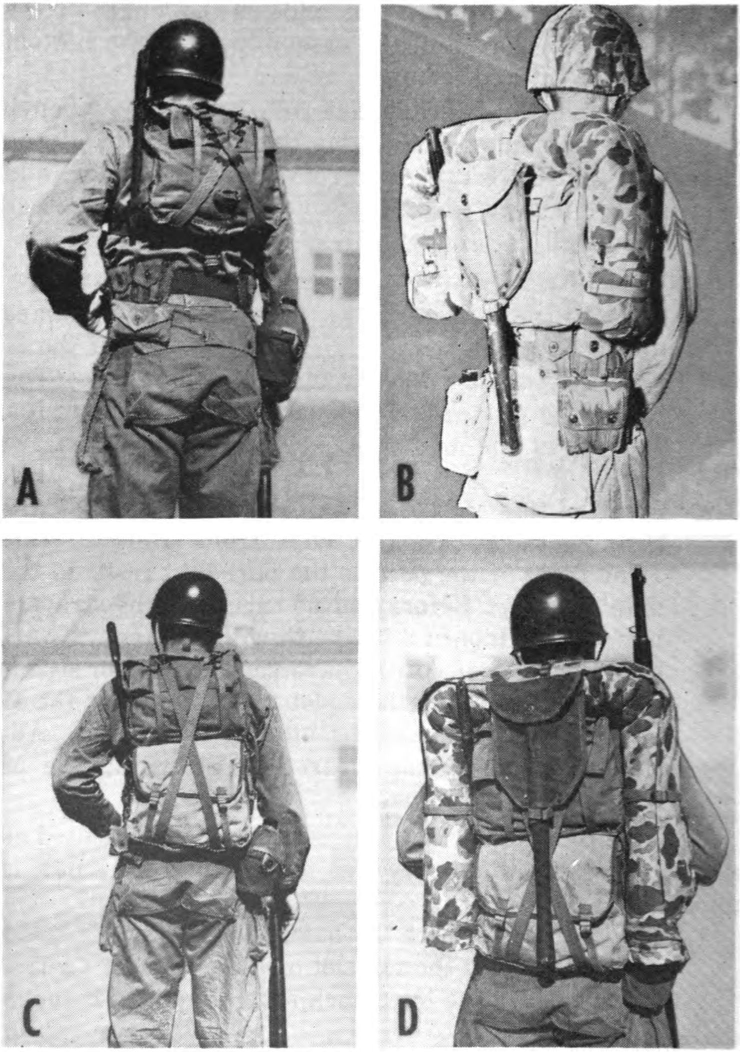


Figure 13–20.—Standard pack assemblies. A. Light marching pack. B. Field marching pack. C. Transport pack. D. Field Transport pack.

back upon itself and through the haversack suspender keeper on the broad part of the suspender.

3. Pass the ends of the belt suspender pack straps through the haversack pack strap loops from front to rear. The belt suspenders do NOT go over the shoulders. They pass under the pack and support it. Give the pack straps a half turn outboard before passing them through the loops, to make them lie flat against your body.
4. Cross the pack straps behind the haversack.
5. Now couple the belt suspender snaps to the haversack suspender M buckles.
6. Try on the pack without the cartridge belt. Adjust pack straps and haversack suspender straps until the pack feels comfortable. Remember that the belt does NOT hold the pack down. The suspenders and belt supports should hold the belt up. (This is true also when only the belt and suspenders are worn.)
7. Put on the belt and fasten the belt suspender hooks into whichever eyelets along the top edge of the belt will provide the most comfort. Hook the haversack belt supporting strap into center rear eyelet on the belt.

FIELD MARCHING PACK. This assembly is used when you are going to bivouac. First assemble the short blanket roll and the marching pack as described above. Bend the blanket roll around the haversack sides so that the free edge of the shelter half will shed water. Then use three blanket roll straps to secure the roll to the haversack.

Carrying Other Landing Party Equipment

HELMET AND ACCESSORIES. The helmet is designed to give maximum protection to the forehead, temples, and back of the neck. The liner headband, helmet chinstrap, and liner chinstrap must be adjusted to conform with the size of the man's head. Here is how to fit the helmet properly:

1. Set squarely on the head with:
   a. Forward edge of the helmet on line and level with the eyebrows.
   b. Rear edge of the helmet low over the neck and parallel to the deck.
   c. Lobe of the ear, only, showing.
2. Chinstrap of the helmet must be kept firmly fastened under the chin.
3. Liner chinstrap must be tightly secured up and over the front edge of the helmet.

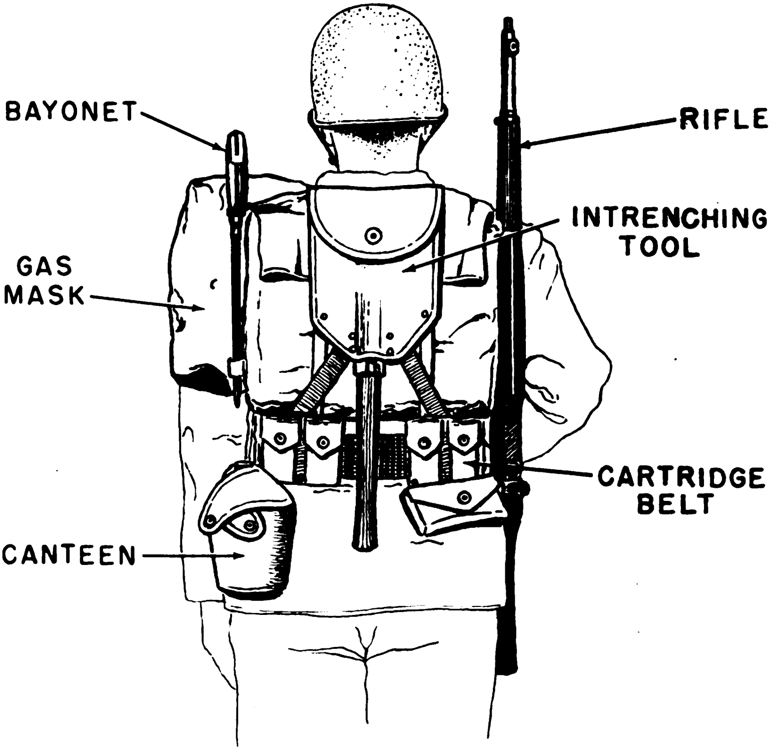


Figure 13–21.—Marching pack worn with rifle and gas mask.

Remember that your helmet may one day save your life. DON'T use it as a shovel, DON'T sit on the liner or use it as a pillow, and DON'T use it as a cooking pot on bivouac. (The heat can ruin its temper.)

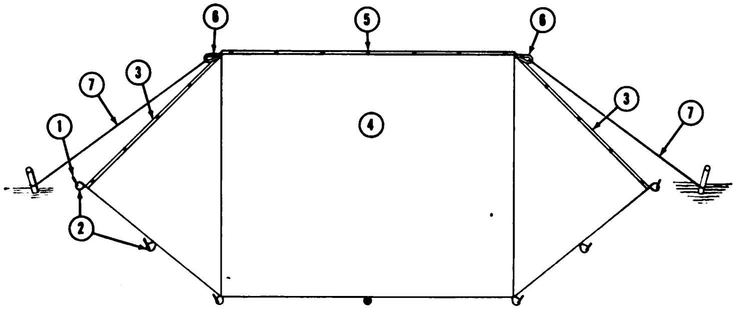
GAS MASK AND CARRIER. You can carry your mask in several positions. Use the position most favorable to the occasion and your other equipment. The side carry position can be used with the Navy Mk 4 Mask (shipboard type) or the Army lightweight service mask (for land use). Figure 13–21 shows another way to carry the gas mask.

BAYONET AND SCABBARD. When worn on the cartridge or pistol belt, hook the scabbard to eyelets of the belt at a point opposite the left hip. When carried on the haversack, hook the scabbard to the bayonet attachment and pass the scabbard through the bayonet loop (fig. 13–21).

How to Use the Shelter Half

Normally, each individual in the landing party carries one half of a shelter tent, with the required number of pins and poles (one guy line, five tent pins, and one tent pole). Two men carry and occupy one complete tent.

When properly instructed, two men should be able to erect a shelter tent (also called a "pup" tent) in five minutes. Here is the basic method (fig. 13–22):



1. TENT PINS
2. FOOT STOP LINES
3. DOORS
4. SHELTER HALF
5. BUTTONS
6. LOOP
7. GUY LINES

Figure 13–22.—Erecting a shelter tent.

Pairs of men pitch tents together. Each man spreads his shelter half. The shelter halves are then buttoned together. One man slips his pole into the eyelets in the front of the tent and holds the pole upright.

The other man pins down the front corners of the tent in line with the pole, then pins down the front triangle of the tent, and drives the guy pin two-and-a-half pin lengths in front of the front triangle. He places the loop of the guy over this pin, runs the other end of the line through the loops of the shelter halves, and ties it, making sure that the pole is vertical when the line is taut (fig. 13–22). He then adjusts the rear tent pole through the eyelets in the rear of the tent. The first man pins down the rear corners of the tent, drives in the rear guy pin so that it is two-and-a-half tent pin lengths from the rear pin of the triangle, then adjusts the guy line. Then they pin down the sides.

Remember that this is only a basic method. The *Landing Party Manual* describes a drill method that is performed "by the numbers," but is similar to the one above.

To strike pup tents, first unbutton enough buttons so that each man can grasp a tent pole and pull them to the left or right. When the tent is flat on the ground, pull the pins, finish unbuttoning the halves, and roll the packs.

SUMMARY

In this chapter we have studied all the single-shot and semiautomatic small-arms weapons that are included in the small arms and landing party equipment of most U. S. naval vessels. (We didn't take up the caliber .45 line-throwing gun, which is not used as a weapon; this was covered in the course for GM3.) For all these weapons we discussed maintenance inspection, gaging, and testing. Except for the caliber .45 pistol and caliber .30 rifle, we also took up the construction, functioning, and operation of each weapon, and specified references for further study where available. We then took up hand grenades, and wound up the chapter with a discussion of how to use the

M1941 pack and its components, and how to set up pup tents.

In the next chapter we'll go into detail on automatic weapons and small-arms ammunition.

QUIZ

In each of the following multiple-choice questions, select the one BEST answer.

1. Which of the following parts of the .45 pistol M1911A1 is exactly the same as the corresponding part in the caliber .22 (Ace) pistol?
   a. Barrel
   b. Slide
   c. Magazine
   d. Ejector
2. The firing pin tang is aligned with a slot in the bridge of the M1 carbine's receiver only when
   a. the bolt is locked
   b. the trigger is squeezed
   c. the safety is off
   d. the hammer strikes the firing pin
3. In the M1 carbine, the ejector is located in the
   a. receiver
   b. slide
   c. gas cylinder
   d. bolt
4. The headspace of most small-arms weapons is measured between the
   a. face of the bolt and the base of the cartridge when the bolt is retracted
   b. tip of the firing pin and the cartridge primer when the round is rammed home
   c. shoulder of the chamber and the head end of the cartridge when the bolt is closed
   d. forward end of the chamber and the face of the bolt when the bolt is closed
5. If the bolt of a small-arms weapon closes on the "maximum" headspace gage,
   a. headspace adjustment is OK
   b. headspace is too great for safety
   c. headspace is not great enough for safety
   d. the "minimum" headspace gage should be used instead of the "maximum" gage

6. How are fired cases normally ejected from the caliber .38 revolver?
   a. Manually after each shot
   b. Manually after the cylinder contains no more live rounds
   c. By recoil action after each shot
   d. By trigger action after the cylinder contains no more live rounds.
7. You are performing safety tests on a caliber .45 pistol M1911A1. The slide has been partly retracted. While the slide is moving forward you maintain a steady pressure on the trigger. The hammer falls. This indicates that
   a. the pistol is functioning properly
   b. the sear or the hammer is faulty
   c. the safety lock is not safe
   d. the disconnector is worn
8. On the Winchester shotgun M97, which of the following does NOT automatically result when the weapon is set at SAFE?
   a. The trigger locks
   b. The action slide handle locks
   c. The action slide lock disengages
   d. The hammer is at half cock
9. Which of the following types of grenades has no explosive filler?
   a. Training grenades
   b. Practice grenades
   c. Chemical grenades
   d. Offensive grenades
10. Which of the following is NOT a part of the marching pack?
   a. Haversack
   b. Knapsack
   c. Belt suspender
   d. Cartridge belt

CHAPTER 14

SMALL-ARMS AMMUNITION AND MACHINE GUNS

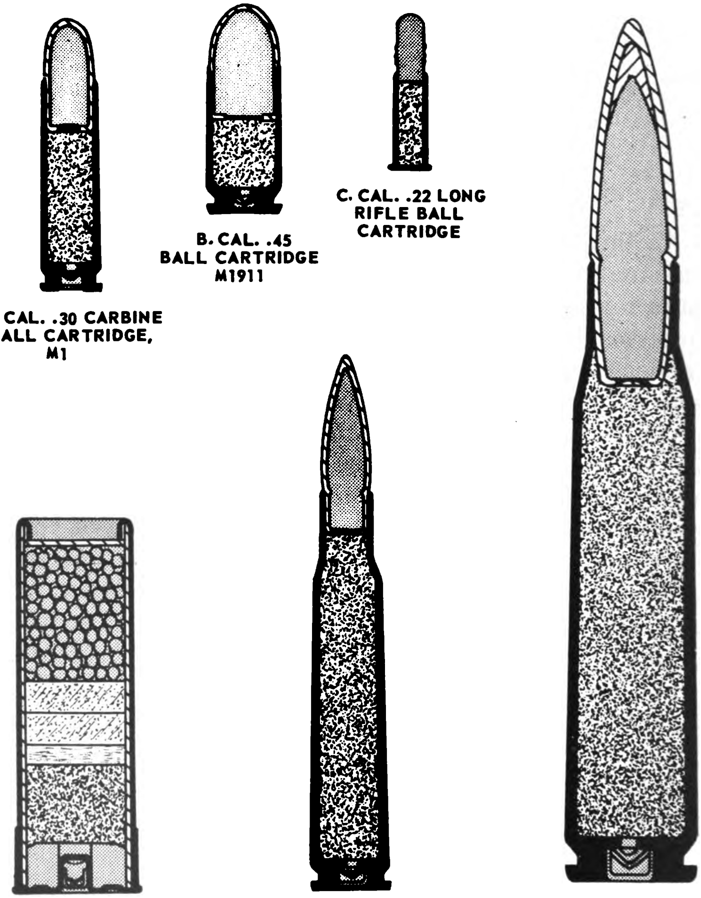
INTRODUCTION

In this chapter we take up small-arms ammunition and automatic weapons. We'll go into the construction and functioning of the important types of small-arms ammunition, then discuss the construction, operation, maintenance inspection, gaging, and testing of caliber .30, caliber .45, and caliber .50 automatic weapons.

As in the preceding chapter, it's assumed that you're acquainted with small-arms ammunition and automatic weapons to the extent that they were taken up in the preceding course in this series. In the beginning of chapter 13 we briefly reviewed small-arms functioning principles and nomenclature. For details that aren't covered in this chapter, look up the references mentioned, especially Army technical manuals TM 9–2205 for the principles of small-arms weapons construction and functioning, TM 9–2200 for pictures and capsule descriptions of all small-arms weapons now standard in the Navy and the Army, and TM 9–1990 for exhaustive details on small-arms ammunition.

SMALL-ARMS AMMUNITION

The Army and the Marine Corps, who are the main users of small-arms weapons and ammunition, recognize broadly as "small-arms" any weapon that the individual infantry-man or Marine carries and fires. Until a few years ago, this was the same as saying that small arms were small-bore weapons up to about caliber .50. The only exceptions were mortars and grenades. But today the exceptions have multiplied. Infantrymen and Marines now have rockets, recoilless rifles, flame throwers, and a



A. CAL. .30 CARBINE BALL CARTRIDGE, M1

B. CAL. .45 BALL CARTRIDGE M1911

C. CAL. .22 LONG RIFLE BALL CARTRIDGE

D. 12 GAGE SHOTGUN SHELL

E. CAL. .30 BALL CARTRIDGE, M2

F. CAL. .50 BALL CARTRIDGE, M2

Figure 14–1.—Types of small-arms ammunition. Cross sections.

greater variety than ever of grenades and mortars. So, for them, the term "small arms" has broadened to take in this new heavy stuff. But sailors are not specialists in ground fighting, and the *Landing Party Manual* provides only for small-bore weapons, plus grenades. For us, then, small-arms ammunition includes only ammunition up to caliber .50. (Grenades were taken up in chapter 13.)

Small-Arms Ammunition Review

Let's review briefly some fundamentals about small-arms ammunition. It's always fixed ammunition, and the projectile is usually a bullet, though blank ammunition has paper wads, and shotgun shells are loaded with lead pellets. Examples of the calibers of small-arms ammunition for weapons we are concerned with (except caliber .38) are illustrated in figure 14–1. The illustrated sizes are proportional to the actual sizes.

With two exceptions, all ammunition of a given caliber can be used in all small-arms weapons of that caliber. The exceptions are in caliber .45 and caliber .30. The caliber .45–70 blank cartridge (not illustrated) for the line-throwing gun cannot be used in pistols or submachine guns; neither may any ammunition but the .45–70 blank cartridge be used in the line-throwing gun. There are two types of caliber .30 ammunition—that for carbines and that for all other caliber .30 weapons. The latter can be used in caliber .30 rifles, automatic rifles, and machine guns, but not in the carbine; carbine ammunition can be used only in the carbine.

Small-Arms Ammunition Components and Construction

In most types of small-arms ammunition a complete round consists of a cartridge case, primer, propelling charge, and bullet. The cartridge case is made from a circular disc of brass, which is punched into a cup shape, drawn through successive dies into final shape, machined for the extractor groove at the base, then annealed for hardness and toughness. (Cartridge cases for certain calibers may be made of steel or of other alloys.) The primer is then pressed into a cavity in the cartridge base, called the primer pocket, and staked or crimped. The joint is sealed by shellac or lacquer, the propellent powder is measured out and loaded, and the bullet inserted and crimped into place. That in general is how a round of small-arms ammunition is manufactured. Let's now take a more detailed look at these components (fig. 14–2).

CARTRIDGE CASES can be divided into RIMFIRE and CENTERFIRE types. The caliber .22 cartridge (shown in cross section in fig. 14–1) has its primer compound distributed around the rim of its base; this is a typical rimfire cartridge. All the other small-arms ammunition illustrated is of the centerfire type, with the primer in the center of the base.

Centerfire cartridges may be either RIMMED, SEMI-RIMMED, or RIMLESS. Rimmed cartridges are somewhat like the .22 caliber rimfire case illustrated in figure 14–1; the rim at the base is larger in diameter than the case. In rimless cartridges (fig. 14–2) there is a ring-shaped groove near the base instead of a protruding rim. Semi-rimmed cartridges have both a protruding rim and a groove. All the caliber .30, caliber .50, and caliber .45 ammunition you'll deal with (except the line-throwing gun's rimmed caliber .45–70 cartridge) is rimless. The special caliber .38 ammunition used in the S&W revolver described in chapter 13 is rimmed.

You'll also find variations in the shape of the forward end of the cartridge. It can be STRAIGHT (example: caliber .45 in fig. 14–1), STRAIGHT TAPER (caliber .30 carbine), or BOTTLENECK (caliber .30 or caliber .50).

PRIMERS. The primer, which is crimped into the primer pocket in centerfire cartridge cases, has as its main components a soft metal CUP, a PRIMER COMPOSITION sensitive to impact, and a brass ANVIL. (See fig. 14–2.) A paper disk protects the primer composition from moisture. The firing pin's impact on the cup drives it against the anvil, and the blow ignites the primer composition,

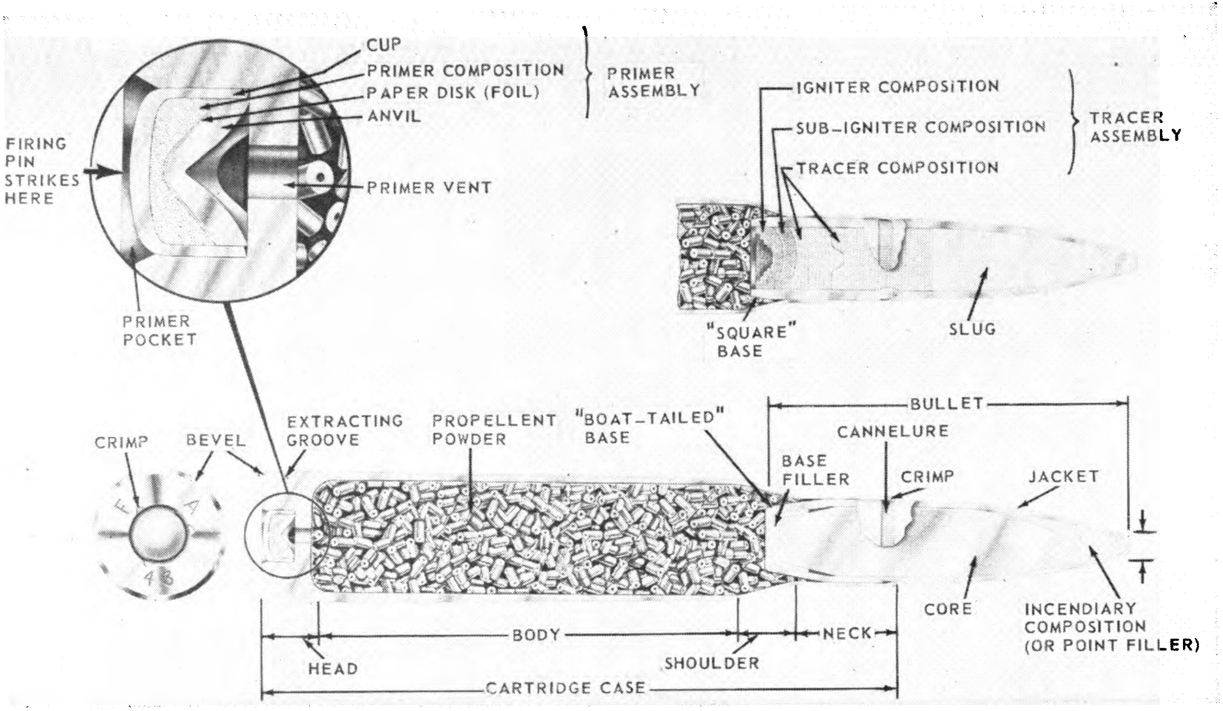


Figure 14–2.—Details of small-arms ammunition construction.

which sends a blast of flame through the primer vent into the propelling charge.

In rimfire cartridges the primer composition has no special structure of its own, but instead is distributed around the rim, as shown in figure 14–1. The weapon's firing pin strikes the rim and indents it to initiate the primer compound.

PROPELLING CHARGES. Depending on the type of ammunition, caliber, and date of manufacture, the propelling charge may be any of several varieties of smokeless powder. The commonest is nitrocellulose (pyro) powder with diphenylamine stabilizer, like that used in the naval gun ammunition you're already acquainted with, but there are also double-base propellants and some composed of mixtures of black powder and guncotton.

BULLETS vary considerably in composition and structure, depending on their caliber and purpose. Caliber .22 bullets are of lead. Some caliber .22 and .38 bullets are of a lead-antimony alloy, harder than straight lead. In high-velocity weapons and in semiautomatic or automatic weapons something harder than lead is needed, and the lead- or steel-cored bullet is jacketed by GILDING METAL—a copper-zinc alloy. Or the jacket may be of steel coated with gilding metal. Armor-piercing ammunition in calibers .30 and .50 is of hardened alloy steel, jacketed with gilding metal or with gilding-metal clad steel jackets.

Bullets may be either round headed (for example, caliber .22 and caliber .45 ball) or ogival like projectiles used in larger Navy guns. And they may be either boat tailed or square tailed. Both types are shown in figure 14–2. The figure also shows how incendiary and tracer compositions are applied to the bullet.

Small-arms bullets have no recognizable rotating bands as such, since the gun rifling engraves the soft metal of the bullet surface. But they may have CANNELURES or grooves used for lubricant coatings and to help make a firm connection with the cartridge case.

Types of Small-Arms Ammunition

Now that we've investigated the anatomy of small-arms ammunition generally, let's consider the specific types available in each caliber.

CALIBER .22. The cartridge, ball, caliber .22, long rifle, is for use in the .22 caliber pistol and rifle for training purposes. These cartridges are procured from several commercial manufacturers. They come in wooden packing boxes, with the lot number stamped on each box and on the cartons inside for identification. The cartridge case is of brass, copper, gilding metal, or of steel—zinc-plated or parkerized, and oiled.

The bullet is made of lead and contains grease or wax lubricant in its cannelures.

CALIBER .30 (RIFLE). The types of ammunition most commonly used for caliber .30 rifles and machine guns are:

Armor-piercing (AP).—This cartridge is intended for use against personnel, light armor, and light materiel. The complete round is 3.34 inches long and has a black bullet tip for identification. The bullet, which is 1.39 inches long overall, consists of a gilding metal jacket, a hard alloy steel core, a lead "T" shot point filler, and a gilding metal base filler.

Armor-piercing incendiary (API).—This cartridge is intended for use in both aircraft and ground machine guns. The cartridge is 3.34 inches long and may be identified by its aluminum-color bullet tip. The bullet has an armor-piercing steel core with an incendiary mixture in place of the lead point filler. It is 1.44 inches long.

Ball.—This is the commonest type. It is used against personnel and light targets, and is issued for guard purposes. Cartridge length is 3.34 inches. There are no markings on the bullet tip. The bullet, 1.123 inches long, has a gilding metal or gilding-metal clad steel jacket and a lead-antimony alloy core.

Incendiary.—This cartridge is one you're not likely to encounter, since it's issued for aircraft machine guns. It has a blue bullet tip.

Tracer.—The type of tracer cartridge we are mainly concerned with is the M25, issued for use in observation fire in ground machine guns. (But it can be used in rifles.) When fired, the trace is dim for a short distance of flight from the muzzle, but then becomes bright. The cartridge is 3.34 inches long and has an orange bullet point. The bullet has a gilding-metal clad steel jacket, a lead alloy slug, and a tracer and igniter composition in its base. (A red bullet nose indicates an M1 tracer, which produces a bright red trace. This type is normally issued for aircraft use.)

Blank.—This cartridge is used in rifles for simulated fire during maneuvers, for signaling purposes, and for firing salutes. It has no bullet. A paper cup or wad is inserted into the neck of the case against the cannelure and sealed in place with lacquer. The mouth of the case is then crimped to keep the wad in place.

Dummy.—This cartridge is used for training personnel in rifle operation, and in functioning tests and inspection of weapons. The hollow cartridge case has three holes and no primer. The bullet has a gilding metal or gilding-metal clad steel jacket with lead alloy core.

CALIBER .30 CARBINE ammunition can be used only in the caliber .30 carbine. In this course we discuss the ball and dummy cartridge only.

Ball.—The caliber .30 cartridge, ball, carbine is intended for use against personnel and light targets at ranges up to 300 yards. The bullet has a lead alloy core and jacket of either gilding metal or gilding-metal clad steel.

Dummy.—This is used for training personnel in carbine operation and for inspection of weapons. Dummy cartridges have an empty primer pocket and two holes in the side of the case.

CALIBER .38 (REVOLVER). For the caliber .38 revolver issued in the Navy (see chapter 13 for details) there is issued caliber .38 SPECIAL ball ammunition with bullets weighing 158 grains. NEVER attempt to use regular .38 ammunition in the .38 S&W special revolver.

Both Colt and S&W make ball ammunition that fits the caliber .38 S&W special revolver. The only difference is that S&W's has a round tip, and Colt's is flattened. The bullet is of lead, and is crimped into the cartridge case. There are also available a similar ball cartridge with its bullet encased in a copper-plated steel jacket, two tracer types (one with 120-grain bullet, the other with 158-grain bullet), and a blank round (no bullet).

CALIBER .45. We'll take up only ball and dummy ammunition used in caliber .45 pistols and submachine guns.

Ball.—This cartridge is used against personnel and is the type issued for guard purposes. The cartridge is 1.275 inches long. The bullet, 0.68 inches long, has a gilding-metal, gilding-metal clad steel, or copper-plated steel jacket, and a slug of lead alloy.

Dummy.—This cartridge is used to train in weapon operation and for functioning tests and inspection. It has an empty primer pocket and two holes drilled in the side of the case.

CALIBER .50. Ammunition most commonly used for caliber .50 machine guns includes:

Armor piercing (AP).—This cartridge is effective against lightly armored or unarmored vessels, armored aircraft, armored vehicles, concrete shelters, and other bullet-resisting targets. The cartridge is 5.45 inches long. It has a black bullet tip. The bullet, 2.31 inches long, has a gilding metal jacket, a hardened core of tungsten-chrome or manganese-molybdenum steel, and a point of antimony-lead alloy.

Armor-piercing incendiary (API).—This cartridge contains an incendiary composition to set the target afire. It has an aluminum-painted bullet tip. The bullet's core is the same as that of the armor-piercing bullet, but the point filler is replaced by an incendiary composition (fig. 14–2).

Ball.—Dimensions are the same as for the AP round. The bullet tip is unpainted. The bullet consists of a gilding metal jacket, a soft steel core, and a point filler of antimony-lead alloy.

Tracer.—This cartridge has a red-tipped bullet for a normal or bright tracer and by an orange tip for the cartridge containing a dim or partially dim tracer. The bullet is composed of a gilding metal or gilding-metal clad steel jacket, a hardened lead slug which fills the forward end of the jacket, and tracer and igniter composition filling the remainder.

Dummy.—This cartridge is used for training purposes and for testing gun mechanism. The cartridge case has three holes drilled in its side, and an empty primer pocket. The bullet is a hollow gilding metal or gilding-metal clad steel jacket.

SHOTGUN AMMUNITION. As you know, shotgun ammunition is identified by GAGE; the higher the gage number, the smaller the bore of the weapon in which the ammunition is used. (The only exception is the .410-shotgun, whose bore diameter is .410 in.) The bore of a 12-gage shotgun (the standard size in Navy use) is .729 inch in diameter. A shotgun SHELL contains a quantity of small lead balls or pellets as projectiles, a smokeless powder propelling charge, and a primer located in the center of its base. Balls of pure lead are called SOFT or DROP shot; balls of lead-antimony alloy are called CHILLED shot. All the pellets in a shell are of uniform size, and the sizes are designated by numbers.

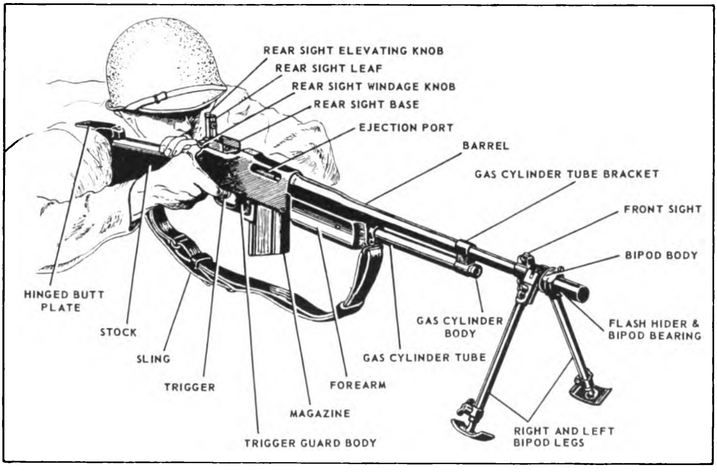
As you remember, the Navy uses chiefly 12-gage, riot-type shotguns for guard work, and the ammunition issued for these is loaded with the heaviest kind of shot—No. 00 buckshot—of which each ball is .34 inch in diameter. Each shell contains 9 balls (total weight: 1⅛ oz), and a propelling charge of 26 grains of smokeless powder.

Shotgun shells are procured from several manufacturers. They have metal heads and waterproofed paper cases (though you may occasionally come across shotgun shells with brass cases, like the one illustrated in cross section in figure 14–1). The wad on top of the shell and the metal head are marked to indicate size and type of load and gage size, and generally show the manufacturer's name or trade mark and trade name.

Now we'll go on to study the automatic weapons that use the caliber .30, .45, and .50 ammunition just described.

BROWNING AUTOMATIC RIFLE M1918A2

The standard automatic rifle issued to U. S. armed forces is the Browning, abbreviated BAR (for Browning Automatic Rifle). (Fig. 14–3.) There is one standard model, the M1918A2. It is a caliber .30, gas-operated, magazine-fed, air-cooled weapon, capable of automatic fire only, though you can fire it single shot if you have a quick, expert trigger finger. The rate of fire can be varied between fast (550 rounds per minute) and slow (350 rounds per minute) by a selector. Its box-type magazine contains 20 rounds of the same ammunition as that fired by the M1 rifle.



Courtesy of Leatherneck Association, Inc.

Figure 14–3.—Browning automatic rifle M1918A2. General view.

The automatic rifle is different from the other weapons that we are taking up in this chapter in that it is less often fired from the hand or shoulder than from a BIPOD. In combat ashore, in fact, it is employed as a light machine gun more than as a rifle.

General Characteristics of the BAR

Length (in.)	47.8
Weight, without bipod and magazine (lb)	16.5
Length of barrel (in.)	24.07
Maximum range (yd)	3,000
Maximum effective range (yd)	500
Rifling	1 turn (RH) in 10 in.
Trigger pull (lb)	6 to 10
Rate of fire (rd/min)	
Normal cyclic rate	550
Slow cyclic rate	350

How to Load and Fire the BAR

LOADING THE BAR MAGAZINE. Hold the magazine in the left hand, top up. Insert the cartridges singly in the top of the magazine, with the cartridges pointing toward the short side of the magazine. With the thumb of your right hand press each cartridge downward until it is held firmly by the lips at the top of the magazine. The magazine holds 20 rounds.

LOADING THE MAGAZINE INTO THE BAR. Press the magazine release and withdraw the empty magazine. Hold a loaded magazine with its base in the palm of your right hand; cartridges point to the front. Insert the magazine between the magazine guides in front of the trigger guard to push it home. Tap the bottom of the magazine to insure that it is seated. The magazine can be inserted with the operating parts either aft or forward. It is ordinarily inserted after the rifle has been cocked.

SETTING THE CHANGE LEVER. Set the lever to "F" for slow fire or to "A" for normal. To set it at SAFE ("S"), depress the change lever stop and push the change lever into position (fig. 14–6).

FIRING THE BAR. To fire, squeeze the trigger. To fire single shots, set the change lever at "F" and quickly squeeze and release the trigger for each shot.

Main Assemblies and Functioning of the BAR

The principal groups of the BAR are the OPERATING GROUP, TRIGGER GROUP, and the BUFFER and RATE-REDUCING GROUP. Other groups are the forearm, bipod, rear sight, and receiver groups.

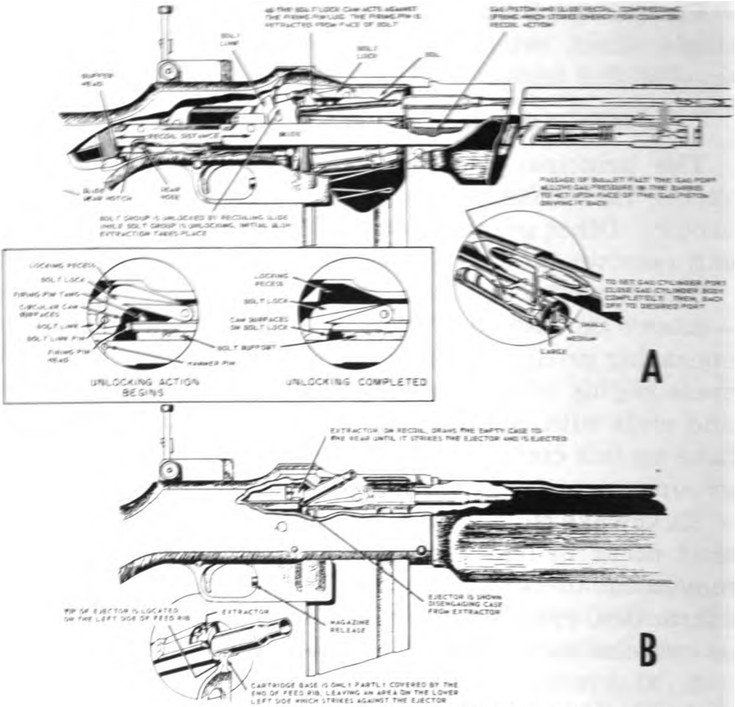
The functioning of the BAR is divided into two phases —REARWARD MOVEMENT and FORWARD MOVEMENT of the operating group, which together make up one CYCLE. The cycle begins with ignition of a cartridge in the chamber and ends with ignition of the next cartridge. We'll first take up this cycle, and then the rate-reducing and trigger groups.

REARWARD MOVEMENT. (See fig. 14–4.) The operations that occur in rearward movement are gas action, slide movement to the rear, unlocking, firing pin withdrawal, extraction, ejection, and termination of movement. Let us examine each of these in turn.

1. *Gas action.* (See fig. 14–4A, inset at right.) When a cartridge is ignited the expanding powder gas drives the bullet through the barrel. As the bullet passes a port in the barrel six inches from the muzzle, part of the high-pressure gas passes into the gas cylinder where it acts on the gas piston while the bullet travels the last six inches of the barrel.

The effect is a sudden blow on the piston, which drives it to the rear, carrying the slide with it. When the piston head passes out of the gas cylinder, the gas expands around it and exhausts through portholes in the gas cylinder tube.

2. *Movement of slide.* (See fig. 14–4A.) As the slide moves to the rear, it compresses the recoil spring. (This stores energy for the forward action.) Before the slide begins to move aft, the hammer pin is about 0.19 inch forward of the bolt link pin. As it


AS THE BOLT LOCK CAM ACTS AGAINST THE FIRING PIN LUG, THE FIRING PIN IS RETRACTED FROM FACE OF BOLT
GAS PISTON AND SLIDE RECOIL, COMPRESSING SPRING WHICH STORES ENERGY FOR COUNTER RECOIL ACTION
BOLT LINK
BOLT LOCK
BOLT
BUFFER HEAD
RECOIL DISTANCE
SLIDE
SLIDE REAR NOTCH
REAR NOSE
BOLT GROUP IS UNLOCKED BY RECOILING SLIDE WHILE BOLT GROUP IS UNLOCKING, INITIAL SLOW EXTRACTION TAKES PLACE
PASSAGE OF BULLET PAST THE GAS PORT ALLOWS GAS PRESSURE IN THE BARREL TO ACT UPON FACE OF THE GAS PISTON DRIVING IT BACK
TO SET GAS CYLINDER PORT CLOSE GAS CYLINDER BODY COMPLETELY. THEN, BACK OFF TO DESIRED PORT
SMALL
MEDIUM
LARGE
LOCKING RECESS
BOLT LOCK
FIRING PIN TANG
CIRCULAR CAM SURFACES
BOLT LINK
BOLT LINK PIN
FIRING PIN HEAD
HAMMER PIN
BOLT SUPPORT
LOCKING RECESS
BOLT LOCK
CAM SURFACES ON BOLT LOCK
UNLOCKING ACTION BEGINS
UNLOCKING COMPLETED
A
EXTRACTOR, ON RECOIL, DRAWS THE EMPTY CASE TO THE REAR UNTIL IT STRIKES THE EJECTOR AND IS EJECTED
EJECTOR IS SHOWN DISENGAGING CASE FROM EXTRACTOR
TIP OF EJECTOR IS LOCATED ON THE LEFT SIDE OF FEED RIB
EXTRACTOR
MAGAZINE RELEASE
CARTRIDGE BASE IS ONLY PARTLY COVERED BY THE END OF FEED RIB, LEAVING AN AREA ON THE LOWER LEFT SIDE WHICH STRIKES AGAINST THE EJECTOR
B

Courtesy of Leatherneck Association, Inc.

Figure 14–4.—Browning automatic rifle M1918A2. Functioning during rearward movement.

moves this 0.19 inch aft, it moves the hammer from the firing pin but does not unlock the bolt.

3. *Unlocking.* (See fig. 14–4A and left inset.) Unlocking begins as the hammer pin passes under the bolt link pin. The bolt link revolves forward about the hammer pin, drawing the bolt lock down and to the rear. The lock and bolt accelerate until the slide has traveled about 1.2 inch, when the bolt lock is completely down, out of the locking recess. It is now supported in front on the bolt supports.

The bolt mechanism begins moving slowly at first and does not reach the speed of the slide until the slide has traveled about 1.2 inches aft. This avoids the shock of a sudden start at the instant the gas strikes the piston, and allows the bullet to clear the muzzle, preventing blowback.

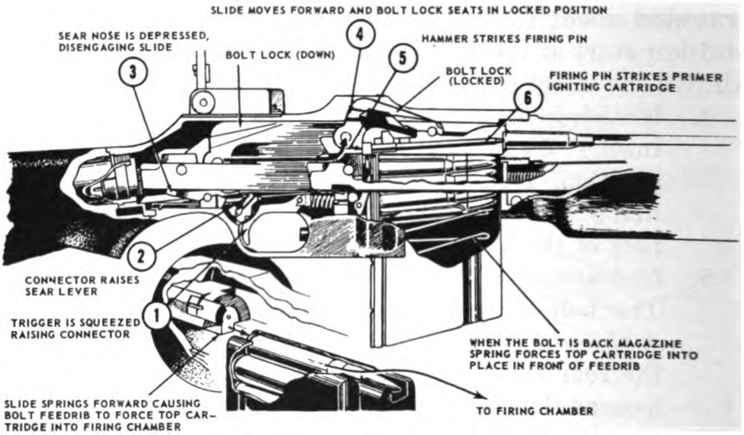
4. *Withdrawal of firing pin.* (See fig. 14–4A and left inset.) As the bolt lock revolves down from locked position, a cam surface in its bottom contacts the firing pin lug, retracting the firing pin from the face of the bolt.
5. *Extraction* (See fig. 14–4A, inset, and fig. 14–4B.) The bolt begins to retract when the circular cam surface on the descending bolt lock's underside cams the rear shoulder of the bolt supports. This action loosens the cartridge case.

The bolt has traveled aft about 5/32 inch when the firing pin is withdrawn, and about 11/32 inch when the bolt lock is completely down. From this point the bolt is drawn to the rear by the bolt lock and bolt link, along with the slide, and carries with it the empty cartridge case which is held firmly on the bolt face by the extractor.

6. *Ejection.* (See fig. 14–4B.) When the slide is about ¼ inch from the end of its rearward travel, the base of the case strikes the ejector, which kicks the case through the ejection opening in the receiver and out.
7. *End or rearward movement.* This phase ends when the rear end of the slide strikes the buffer head and sear release (not illustrated). The recoil spring then pushes the slide forward 1/10 inch. The sear nose (if not depressed) engages the sear notch on the slide and the piece is cocked for the next burst or shot.

FORWARD MOVEMENT. (See fig. 14–5.) Now the BAR begins the second phase of its functioning—forward movement. The steps in this movement are: action of the recoil spring, feeding, locking, and ignition.

1. *Action of recoil spring.* (See fig. 14–5.) When the gunner squeezes the trigger, the connector depresses the sear nose to release the slide, which is driven forward by the recoil spring, carrying with it the


SLIDE MOVES FORWARD AND BOLT LOCK SEATS IN LOCKED POSITION
SEAR NOSE IS DEPRESSED, DISENGAGING SLIDE
3
BOLT LOCK (DOWN)
4
HAMMER STRIKES FIRING PIN
5
BOLT LOCK (LOCKED)
FIRING PIN STRIKES PRIMER IGNITING CARTRIDGE
6
2
CONNECTOR RAISES SEAR LEVER
TRIGGER IS SQUEEZED RAISING CONNECTOR
1
WHEN THE BOLT IS BACK MAGAZINE SPRING FORCES TOP CARTRIDGE INTO PLACE IN FRONT OF FEEDRIB
SLIDE SPRINGS FORWARD CAUSING BOLT FEEDRIB TO FORCE TOP CARTRIDGE INTO FIRING CHAMBER
TO FIRING CHAMBER

Courtesy of Leatherneck Association, Inc.

Figure 14–5.—Browning automatic rifle M1918A2. Functioning during forward movement.

bolt assembly. After about ¼ inch of travel, the feed rib front end contacts the top cartridge, which is forced up by the magazine spring.

2. *Feeding.* This action carries the cartridge forward and the bullet ramp on the breech deflects it upward toward the chamber. The base of the cartridge slides across the face of the bolt and under the extractor.
3. *Locking.* As the slide approaches its forwardmost position, the rear end of the bolt lock is cammed upward about the bolt lock pin into the locking recess, and a rounded surface on the bolt lock slips over the locking shoulder in the receiver. This lock lever action forces the bolt home to its final position. The two locking surfaces on the bolt lock and receiver register as the hammer pin passes under the bolt link pin (reverse of unlocking action previously described). The slide and hammer move forward about 1/10 inch farther to complete the action.
4. *Ignition.* If the sear is down (see below), the hammer strikes the firing pin head, igniting the cartridge.

FUNCTIONING OF THE TRIGGER GROUP. The trigger group is set for the slow cyclic rate when the change lever is on F, for the normal cyclic rate when the change lever is moved to A, and for SAFE when the change lever is on S. Figure 14–6 shows in detail how the trigger group and change lever work.

When the trigger group is set for normal cyclic rate the sear nose stays down as long as the trigger is held back, and the rifle continues firing at a cyclic rate of about 550 rounds per minute until the magazine is emptied or the trigger is released.

When the trigger group is set on F the sear nose is only momentarily depressed when the trigger is held back. At the end of every cycle the sear nose reengages the slide sear notch, and remains engaged until the sear release in the buffer cams the sear down. This reduces the cyclic rate to 350 pounds per minute. Or single shots may be fired for each press and quick release of the trigger.

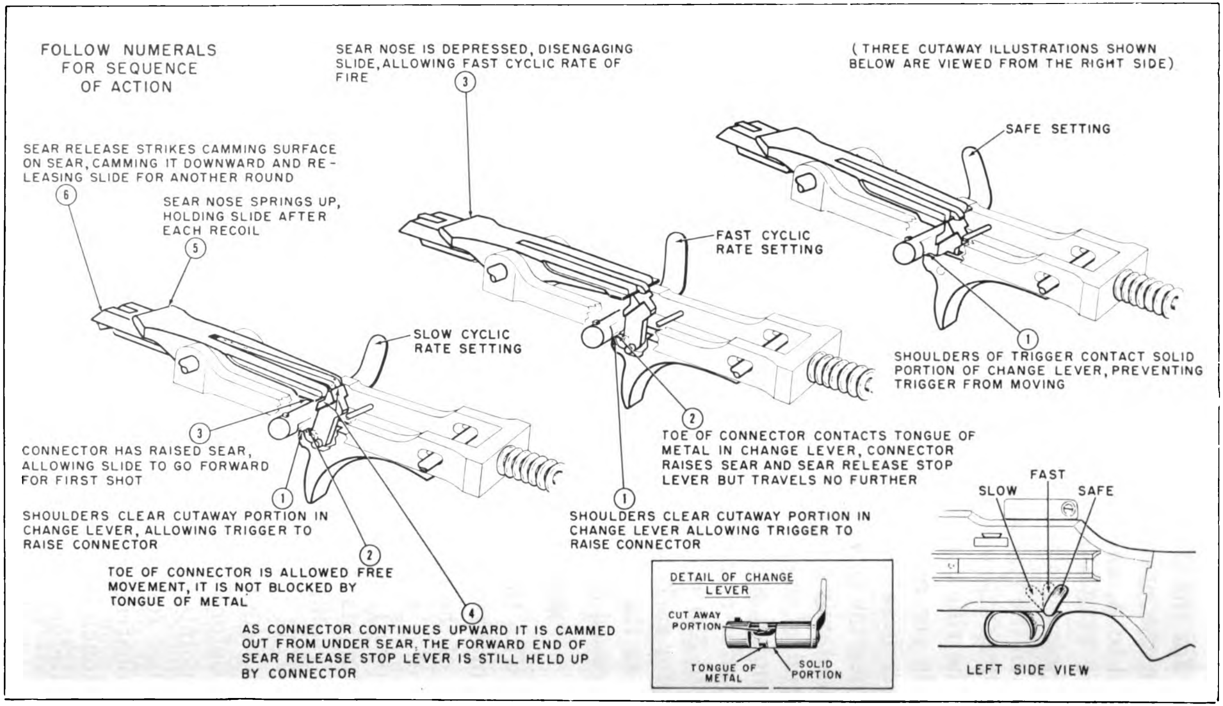
When the trigger group is set at SAFE the sear cannot be released from the sear notch by pressing the trigger.

Maintenance and Inspection of the BAR

As with the other small arms taken up in this chapter, your main concern in this book with regard to maintenance of the BAR (other than routine cleaning and care) is careful periodic gaging, inspection (both visual and functional), and gas port adjustment. For details on other adjustments and repair, and information on tools and gages required, see the Army's maintenance manual, TM 9–1211.

PRELIMINARIES TO INSPECTION.

1. Before inspection, hold each rifle with the muzzle pointed at the floor, clear it, and inspect the chamber for a live round. Be certain that there are no obstructions in the bore of the chamber. Do not touch the trigger until the rifle has been cleared.
2. Before inspection, properly clean the rifle to remove grease, dirt, or foreign matter which might interfere


FOLLOW NUMERALS FOR SEQUENCE OF ACTION
SEAR NOSE IS DEPRESSED, DISENGAGING SLIDE, ALLOWING FAST CYCLIC RATE OF FIRE
3
(THREE CUTAWAY ILLUSTRATIONS SHOWN BELOW ARE VIEWED FROM THE RIGHT SIDE)
SAFE SETTING
SEAR RELEASE STRIKES CAMMING SURFACE ON SEAR, CAMMING IT DOWNWARD AND RELEASING SLIDE FOR ANOTHER ROUND
6
SEAR NOSE SPRINGS UP, HOLDING SLIDE AFTER EACH RECOIL
5
FAST CYCLIC RATE SETTING
SLOW CYCLIC RATE SETTING
1
SHOULDERS OF TRIGGER CONTACT SOLID PORTION OF CHANGE LEVER, PREVENTING TRIGGER FROM MOVING
2
TOE OF CONNECTOR CONTACTS TONGUE OF METAL IN CHANGE LEVER, CONNECTOR RAISES SEAR AND SEAR RELEASE STOP LEVER BUT TRAVELS NO FURTHER
3
CONNECTOR HAS RAISED SEAR, ALLOWING SLIDE TO GO FORWARD FOR FIRST SHOT
1
SHOULDERS CLEAR CUTAWAY PORTION IN CHANGE LEVER, ALLOWING TRIGGER TO RAISE CONNECTOR
1
SHOULDERS CLEAR CUTAWAY PORTION IN CHANGE LEVER ALLOWING TRIGGER TO RAISE CONNECTOR
2
TOE OF CONNECTOR IS ALLOWED FREE MOVEMENT, IT IS NOT BLOCKED BY TONGUE OF METAL
4
AS CONNECTOR CONTINUES UPWARD IT IS CAMMED OUT FROM UNDER SEAR, THE FORWARD END OF SEAR RELEASE STOP LEVER IS STILL HELD UP BY CONNECTOR
DETAIL OF CHANGE LEVER
CUT AWAY PORTION
TONGUE OF METAL
SOLID PORTION
FAST
SLOW
SAFE
LEFT SIDE VIEW

Courtesy of Leatherneck Association, Inc.

Figure 14—6.—Browning automatic rifle M1918A2. Change lever and trigger group functioning

with proper functioning or obscure the condition of the parts. Use a serviceable magazine and dummy cartridges in functioning inspection. Test fire only if it can be done safely where such fire is authorized.

VISUAL INSPECTION. Look at the exterior of the rifle for general appearance, rust, corrosion, and presence of all parts. Then check the details below:

1. Check the following for looseness: Butt stock on receiver, butt plate on butt stock and hinge, swivel bracket on gas cylinder tube, rear sight base on receiver, leaf group on base, front sight base on barrel, blade in base, and flash hider on barrel.
2. Check bipod for proper fit on flash hider, and outer butt plate for proper locking action. If necessary, assemble friction washer assembly with spring to front.
3. See if the butt swivel is free on its bracket.
4. Inspect the bore and chamber for pits, corrosion, and mechanical damage.

FUNCTIONAL INSPECTION.

1. Hand operate to check for functioning and smoothness of operation.
2. Check fit of magazine in receiver, and function of magazine catch and catch release with magazine.
3. Using magazine and dummy cartridges, test the loading function of bolt, and the function of the extractor and the ejector. If neck of ejected case is dented, it indicates that ejection is weak (casing striking side of receiver). This may be caused by bent cartridge neck, worn ejector head, or ejector scraping on bolt.
4. Inspect locking action of bolt lock and bolt.
5. Fire several rounds of service ammunition and examine primers of fired casings. If primer shows indications of being set back in firing pin hole of bolt, due to an enlarged firing pin hole or recessive wear of bolt face, it will be necessary to replace the bolt.

6. Check trigger pull. The procedure is like that described in chapter 13. Trigger pull should be between 6 and 10 pounds.

GAS CYLINDER PORT ADJUSTMENT. The gas cylinder adjustment should be made only if the rifle needs it—for example, if failure to recoil or to eject properly is caused by insufficient gas. Only the gas cylinder parts are to be adjusted. This is the procedure (fig. 14–7):

1. First, unlock the gas cylinder assembly by forcing out the lock, screw the assembly all the way in until it's finger tight, and back off the assembly one complete turn.
2. Turn the cylinder so that the smallest circle passes through the shortest arc to a position under the barrel. Lock the cylinder in place.

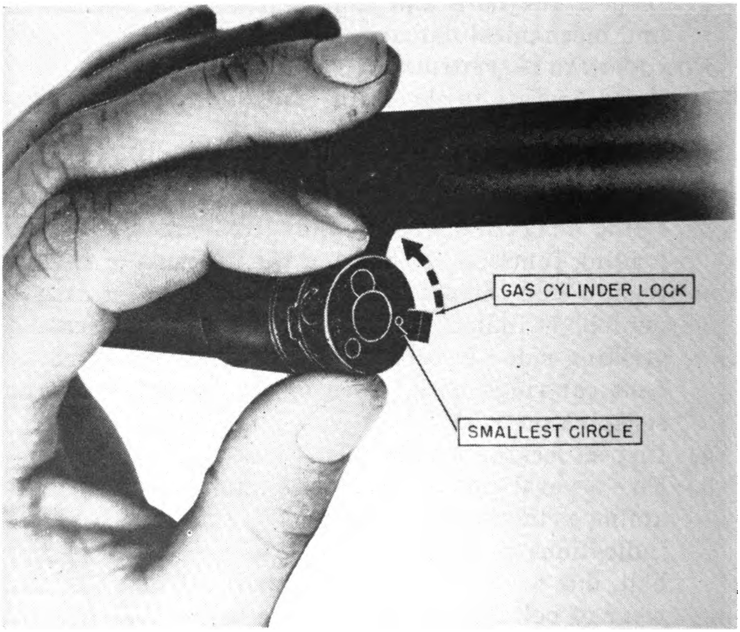


Figure 14–7.—Browning automatic rifle M1918A2. Gas cylinder adjustment.

3. If the weapon still recoils or ejects poorly when fired, rotate the gas cylinder one turn in or out to improve alignment. If such adjustments do not help, turn the cylinder to the next largest circle.

Insufficient gas indicates a clogged or poorly aligned gas port. It is also possible to adjust for too much gas—evidenced by slamming in operation, overheating, and excessive firing rate. And in rare cases poor gas adjustment may permit the gun to fire uncontrolledly. So it's important to check this adjustment.

HEADSPACE GAGING. Every BAR should be headspaced before it is issued to personnel for firing, and after firing exercises. Minimum headspace should be 1.940 inch; maximum should be 1.950 inch. Use gages Z021–7319944 (1.940 in.) and Z021–7314454 (1.950 in.)

BROWNING MACHINE GUN, CALIBER .30, M1919A4

The Browning machine guns (abbreviated BMG) are standard Army weapons used by the Navy in aircraft, ashore, and afloat. The two calibers—.30 and .50—have basically similar mechanisms.

The caliber .30 BMG is issued to combat vessels and many auxiliaries as a landing-force weapon. Its general

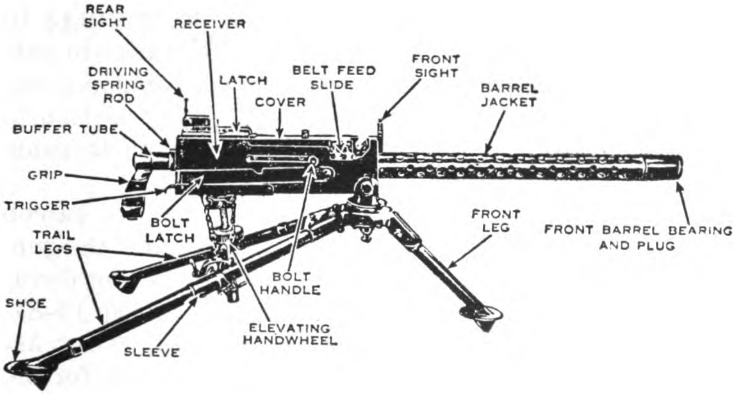


Figure 14–8.—Browning machine gun, caliber .30 M1919A4, on M2 mount.

characteristics are listed below. In this section we'll take up its functioning, operation, and general (nonroutine) inspection and maintenance. For further details, see Army FM 23–55 and TM 9–1205.

General Description

The caliber .30 BMG is a recoil-operated, belt-fed, water- or air-cooled automatic weapon, various models of which are designed for use in aircraft or on ground mounts. The type we shall take up is the M1919A4, illustrated in figure 14–8 on the M2 ground mount. This is an air-cooled weapon designed for use with fabric belts. It has a heavy barrel surrounded with a perforated steel jacket to improve cooling. It uses a leaf-type sight.

General Characteristics of the Caliber .30 BMG M1919A4

Length overall (in.)	41.11
Weight of gun (lb)	31
Weight of tripod mount M2 (lb)	18.75
Length of barrel (in.)	24
Extreme usable range (yd)	2,000
Maximum effective range (yd)	900
Rifling	1 turn (RH) in 10 in.
Trigger pull (lb)	7 to 12
Rate of fire (rd/min)	400-550

Construction and Functioning of the Caliber .30 BMG M1919A4

Figure 14–9 shows the BMG caliber .30 M1919A4 in cross section, with recoiling parts fully forward (in battery). The main exterior structure of the weapon is the RECEIVER, which more or less corresponds in function to the slide of a naval gun. The major recoiling parts inside it are the BARREL, BARREL EXTENSION, and BOLT.

The receiver is supported on pivots by the TRIPOD MOUNT M2, which provides a stable mounting for the gun, is quickly collapsible for transport, and provides for elevation and train of the gun by hand as required (fig. 14–8). At the after end of the receiver is the BACK-PLATE ASSEMBLY (fig. 14–9 again), which has a PISTOL GRIP for the gunner and a BUFFER to take up the shock of recoil of the

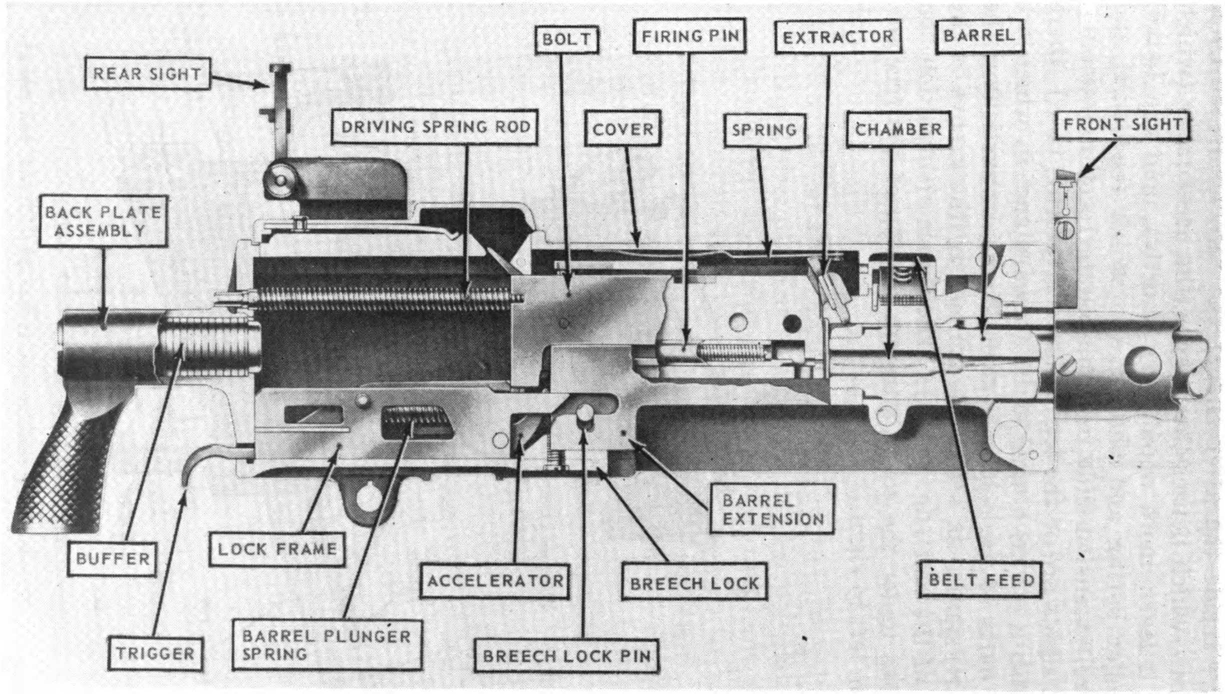


Figure 14—9.—Browning machine gun, caliber .30, M1919A4. Right side, sectional view

bolt. Inside the after end of the receiver is the LOCK FRAME, which houses the trigger, the accelerator (which you'll learn more about very shortly), and the barrel plunger spring and plunger (on which the barrel and barrel extension slide in recoil-counterrecoil movement). The sights are on the top of the receiver (fig. 14–8) ; there is also a COVER, hinged at its forward end, in which are the parts of the belt feed mechanism—in particular, the BELT FEED LEVER—that are cammed by the groove in the top of the bolt (fig. 14–10). The fabric ammunition belt passes under the cover, through the top of the receiver, from left to right.

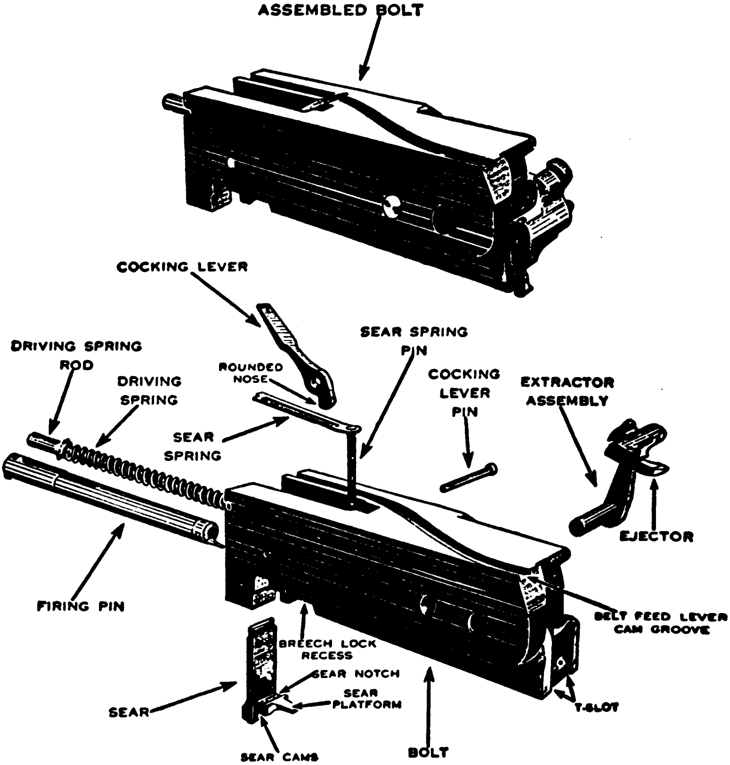


Figure 14–10.—Browning machine gun, caliber .30 M1919A4. Bolt assembly.

The barrel is secured to the front of the barrel extension, which incorporates a barrel locking spring to hold the barrel in place, and a breech locking device which locks the recoiling parts together at the beginning of recoil movement. The BOLT, shown in some detail in figure 14–10, incorporates the sear mechanism, cocking lever and associated parts, and firing pin and spring in its interior. On its face is the EXTRACTOR (which incorporates also the EJECTOR) and a T-slot. In its sides are the recesses in which the breech locking mechanism functions.

Before we go through the functioning cycle of the BMG, notice how the moving parts move:

1. The barrel and barrel extension move in recoil and counterrecoil. The total length of this movement is about 5/8 inch. For the first half of this movement in recoil these parts are locked to the bolt.
2. The bolt also moves in recoil and counterrecoil, but after unlocking from the barrel and barrel extension it's kicked backward by the ACCELERATOR all the way against the buffer.
3. As the bolt moves aft in recoil, the extractor hauls a round out of the belt. As the bolt moves forward in counterrecoil, the extractor is cammed down, pushing the next round to be chambered down into the T-slot in line with the chamber, then up again so that with the ejector it grips the next round in the belt. The sides of the T-slot engage the cartridge base from the time the extractor forces it down into line with the chamber during counterrecoil until, after firing, it's kicked out by the ejector during the next counterrecoil.
4. The accelerator is pivoted on the lock frame. In recoil, its lower part is pushed back by the recoiling barrel extension; its upper end engages the bolt and kicks it back. In counterrecoil, the bolt turns the accelerator forward, unlocking the barrel extension so that it can counterrecoil too.

5. The cocking lever, which is pivoted in the bolt, is cammed by part of the top of the receiver so that its upper end swings forward during recoil and backward during counterrecoil. The lever's lower end pushes the firing pin aft during recoil.
6. The firing pin moves forward in the bolt to strike the cartridge primer when released by the sear, and is pushed backward in the bolt in cocking action during recoil.

We've traced what each major moving part does in the functioning cycle of the BMG. Now let's follow the cycle step by step. Remember that this cycle is practically the same in the caliber .30 BMG and its caliber .50 big brother; if you know one, you know the other. We assume the cycle starts with the gun fully loaded and cocked, and a loaded ammunition belt in the feedway.

1. FIRING. (See fig. 14–11A.) The gunner pulls the trigger. Its forward end lowers as its rear is raised, camming the sear down to release the firing pin's shoulder from the sear notch. The firing pin spring drives the pin into the cartridge primer, igniting the propelling charge.
2. FIRST STAGE OF RECOIL. The bolt, barrel, and barrel extension begin recoiling together. After 5/16-inch movement, the pins on either side of the breech lock contact the camming surfaces on the front of the lock frame, which pull the breech lock down into the barrel extension. This disengages the bolt from the barrel and barrel extension.

Figure 14–11B shows the unlocking. Figure 14–11C shows the camming action and the action of the accelerator at the same time. In its final 5/16 inch of recoil movement, the barrel extension pushes the accelerator aft. The accelerator's tips kick the bolt back and then (as shown in fig. 14–11D) it engages the T-shaped lug of the barrel extension and locks it in recoil position.

3. SECOND STAGE OF RECOIL. (See fig. 14–11E). As the bolt continues to recoil, the extractor hauls the next round out of the belt and the T-slot in the bolt face hauls the empty case out of the chamber. The extractor cam in the cover pushes the extractor down as the bolt moves to the rear. At the end of recoil, the bolt hits the buffer, which brings it to a stop. During recoil also occur the following feeding and cocking operations:
   a. *Feeding.* (See fig. 14–12A and B.) Driven by the camming groove in the bolt, which engages its stud, the belt feed lever pushes the belt feed slide and pawl to the left (position 1). The belt-holding pawl keeps the belt from moving with them.
   b. *Cocking.* (See fig. 14–12C.) As the bolt moves from position 1 (in battery) to position 2 (full recoil), the cocking lever is cammed as shown to retract the firing pin to a point where it can be engaged by the sear notch.
4. COUNTERRECOIL. (See fig. 14–11F.) As the bolt is driven forward by its driving spring, a spring-loaded plunger in the extractor engages cams in the receiver which push the extractor first down, then up, as shown by the arrows. In the downward movement, the extractor pushes the new round into the T-slot on the bolt, and the ejector tip knocks the empty case out of the T-slot. In the upward movement the extractor and ejector are positioned to engage the next round in the belt. As the bolt nears the end of counterrecoil, it pushes the accelerator tips forward, causing the accelerator to unlock the barrel extension, which is then driven forward by the barrel plunger spring. Next, the breech lock cam (shown in figure 14–11B) pushes the breech lock up to engage the breech lock recess in the bolt, so that the barrel extension and bolt reach the end of counterrecoil movement locked together. The

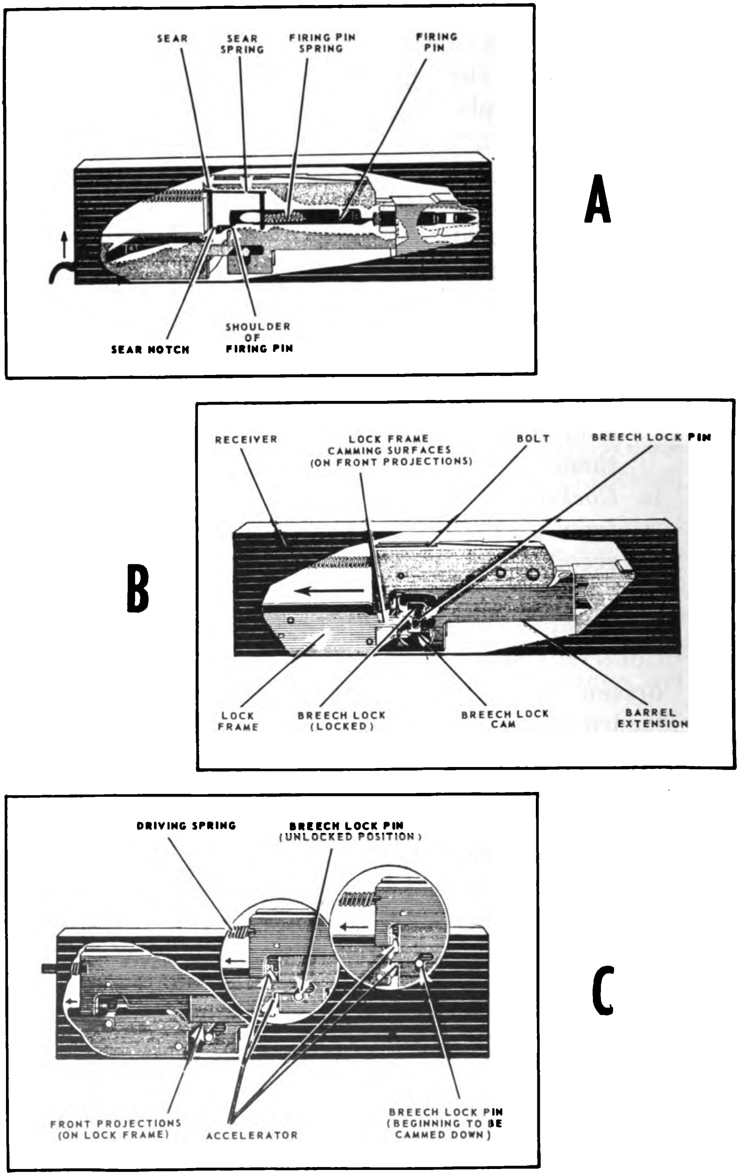


Figure 14–11.—Browning machine gun caliber .30, M1919A4. Functioning cycle. (NOTE: Some parts are omitted for the sake of clarity.)

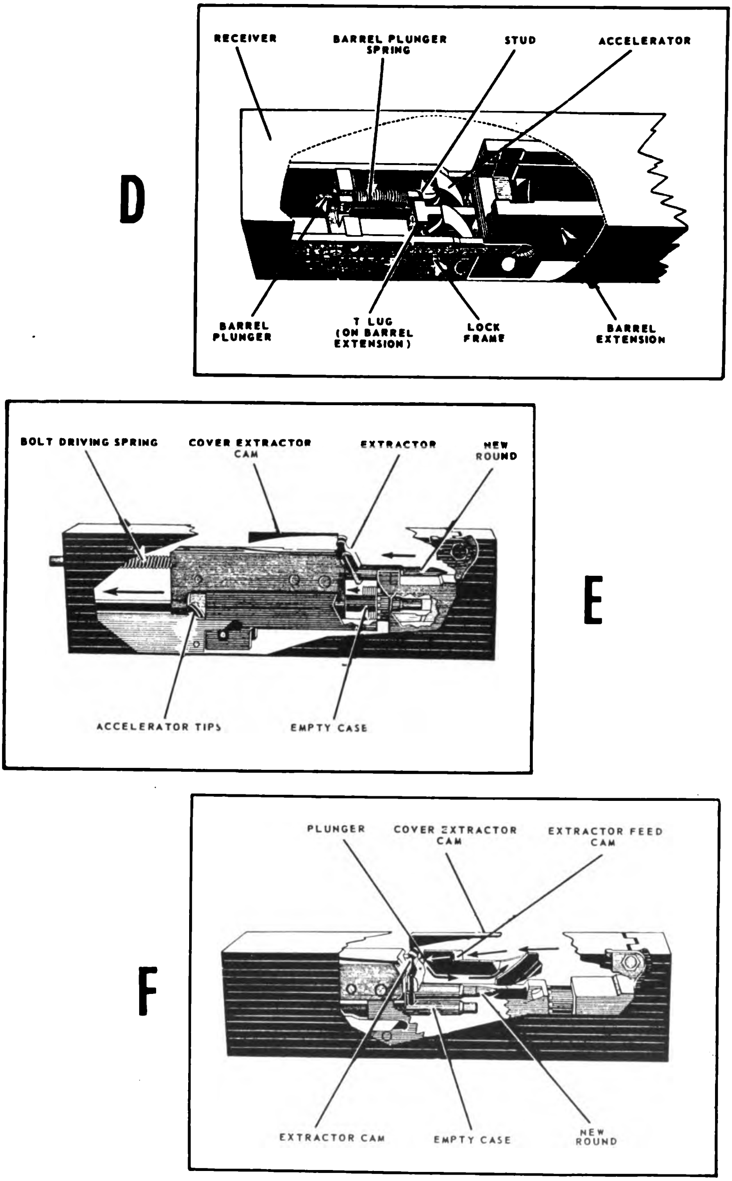


Figure 14—11.—Continued

bolt rams the cartridge home. If the gunner is pulling the trigger, the sear releases the firing pin to fire the next round and repeat the cycle. If the trigger is released, the sear holds the firing pin and the cycle comes to an end with the recoiling parts in battery and the firing pin retracted.

The feeding and cocking operations during counterrecoil are as follows:

a. *Feeding.* (See fig. 14–12A and B.) As the bolt moves forward, the belt feed lever is cammed to push the belt feed slide and pawl to the right (position 2). The pawl moves the belt to the right and positions the next round where the extractor can engage it when the bolt has returned to battery. If because of malfunction the extractor fails to engage and load the cartridge case, the mechanism will go through the motions in the next cycle, but the belt feed pawl will ride on top of the round that should have been loaded, without moving the belt. Thus this arrangement prevents double loading and consequent jamming.

b. *Cocking.* (See fig. 14–12C.) In counterrecoil, the cocking lever starts in position 2 and winds up in position 1, leaving the firing pin engaged by the sear, ready for the next cycle.

The functioning cycle continues so long as the trigger is pulled and the ammunition belt continues to supply fresh cartridges.

Operation of the Caliber .30 BMG M1919A4

The basic operations for this weapon are HALF LOADING, LOADING, UNLOADING, and CLEARING.

TO HALF LOAD the BMG M1919A4, with cover either open or closed, insert the belt into the left side of the feedway, and pull it through until the first round is positioned to the right of the belt-holding pawl. Close the cover, if open. Pull the bolt by its handle fully to the

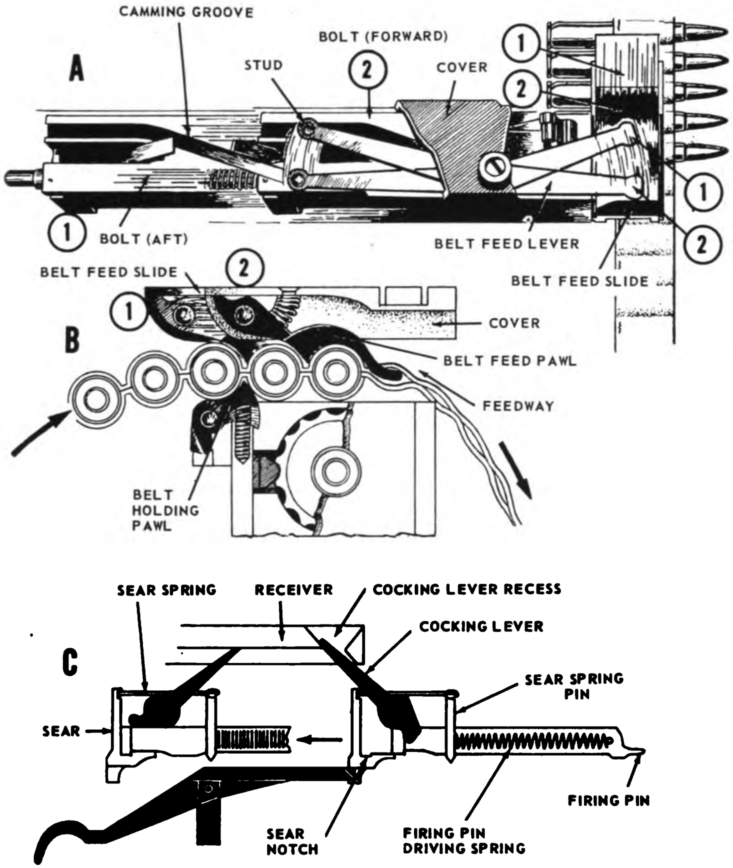


Figure 14–12. Browning machine gun, caliber .30, M1919A4. A. and cycle. (NOTE: Some parts are omitted for the sake of clarity.)

rear, and release. This cocks the firing pin and shifts the first round to the centerline of the gun, so that the extractor grips it as the bolt slides into battery.

But the round is not yet chambered, and the gun cannot be fired. The cartridge does not go into the chamber until the bolt has been operated a SECOND time, for FULL LOAD. The caliber .30 M1919A4 BMG is unlike all other small-arms weapons we have so far studied in that after the ammunition-carrying device (in this case the belt) is loaded into the weapon, the bolt must be worked manually through TWO operating cycles before it can be fired.

The HALF-LOAD position can therefore be considered as a safe-but-loaded condition for the caliber .30 BMG. Actually, the weapon has no real safety of the type we have so far found on small-arms weapons and machine guns; it is ALWAYS ready to fire when a round is chambered. It is important to remember this when you're operating the gun; it must always be CLEARED if it is not to be fired.

For FULL LOAD, then, you pull the bolt handle back twice after inserting the ammunition belt. The gun can then be fired by pulling the trigger.

To UNLOAD, raise the cover, lift out the belt, pull the bolt to the rear and hold it, and look or feel to make sure there is no ammunition in the gun. Then lower the extractor, release the bolt, position the belt feed lever stud over its groove in the bolt, and lower the cover. Last, pull the trigger to uncock the firing mechanism.

To CLEAR GUN, raise the cover, remove the belt, pull the bolt to the rear and secure it in its rearward position by engaging the extractor cam plunger in the rear of the extractor feed cam, and inspect gun to see that no ammunition is in the chamber.

Maintenance Inspection and Headspace Adjustment of the Caliber .30 BMG M1919A4

Complete inspection of the M1919A4 BMG requires, because of the complexity of the weapon, fairly detailed instructions which we haven't space to go into here. Unless your job requires that you become a BMG specialist, don't go any further than field-stripping the weapon and making the other inspections and adjustments covered in this section. For further information on inspection, adjustment, and repair of the weapon, see Army FM 23–55 and TM 9–1205.

VISUAL INSPECTION. Before going into detailed inspection, look the weapon over generally for damage and for missing parts. See that all rivets, screws, and so forth are in place and secure in the receiver group. Further details to look for are:

1. Check general alignment of sights.
2. Check the back plate to see that it fits snugly in the side plate grooves, and check the condition of the grooves.
3. Lift the cover and retract the bolt handle. See if the firing pin protrudes properly (there is a gage for this but in this preliminary inspection you needn't use it) and if the T-slot is smooth and free of brass and other residues. Look also to see if the recoil plate in the face of the bolt is free of corrosion and carbon.

FUNCTIONAL INSPECTION.

1. Check headspace. No gage is used for this purpose. Retract the bolt about 1 inch, then ease it forward slowly. The moving parts should not bind, and they should yield a solid metallic sound when they go into full battery.

   The headspace adjustment is correct when, as the bolt closes,
   a. the breech lock rides smoothly up the breech lock cam into its fully locked position, in positive contact with the forward wall of the breech lock recess.
   b. the forward end of the bolt is positioned against the rear end of the barrel.
2. Pull the bolt back, but do not release. Allow the bolt to move slowly forward, and see if it binds at any point. If it moves freely, repeat with a dummy cartridge. If it binds, determine the exact points at which it binds.
3. Check trigger pull. It should be between 7 and 12 pounds.
4. Check the barrel and barrel extension to be sure they do not bind at any point.

5. Operate the bolt with cover open and closed, and check feeding action. The feed mechanism should move freely in its full travel in both directions.

HEADSPACE ADJUSTMENT. The BMG 1919A4 headspace adjustment (distance between the face of the bolt and the rear of the barrel) is made WITHOUT using a gage. Here is the procedure (fig. 14–13):

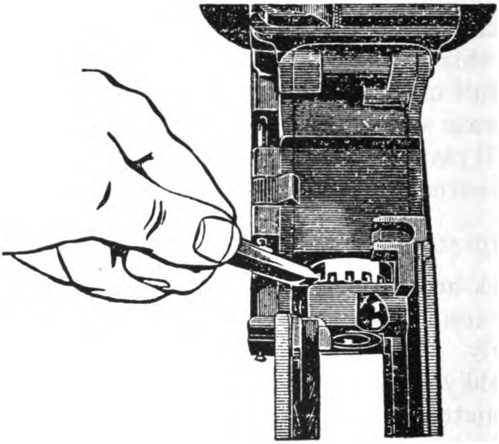


Figure 14–13.—Browning machine gun, caliber .30, M1919A4. Adjusting headspace.

1. Pull the bolt to the rear approximately ¾ inch, and disengage the barrel locking spring.
2. Using the proper combination tool, or the nose of a cartridge, in the barrel notches, screw the barrel into the barrel extension until the recoiling parts will not go into battery under pressure of the driving spring when the bolt handle is released.
3. Unscrew the barrel from the barrel extension one notch at a time (checking after each notch) until the barrel and barrel extension will just go fully forward into battery without being forced. (See item No. 1 under FUNCTIONAL INSPECTION above.)
4. Unscrew the barrel one additional notch, and engage the barrel locking spring.

5. After the correct headspace has been determined, mark the notch in the barrel in which the barrel locking spring is engaged. This will simplify making the headspace adjustment if the gun is disassembled and reassembled in the future. The adjustment is important. Tight (insufficient) headspace will cause poor timing of locking and unlocking and consequent damage to the barrel extension, bolt, or breech lock. Excessive headspace leaves too much play between bolt and barrel, and may result in ruptured cartridge cases and possible injury to the gunner.

CALIBER .45 SUBMACHINE GUNS

Although the name may give you a false impression, the submachine gun is not, in the strict sense, a light machine gun. It's more accurate to think of it as a sort of king-size pistol, with a bigger magazine and the ability to fire in full automatic. It resembles the pistol also in that it has a comparatively short barrel, and fires a heavy (caliber .45) slug that can deliver a powerful punch at short range. However, it is too large to be a hand weapon.

The submachine guns standard for issue to U. S. naval personnel are the M1928A1, the M1, the M1A1, and the M3. (There is also an M3A1, but it isn't procured for naval personnel and will not be discussed here.) The M1928A1, M1, and M1A1 are of basically similar Thompson design (hence the name "Tommygun"). The M3 is a World War II design, much simpler in construction and easy to maintain, and just as effective, if not as handsome.

All these submachine guns are air-cooled, blowback-operated, magazine-fed shoulder weapons. The M3 can be fired in automatic only; the M1 and M1A1 can be fired either in automatic or in semiautomatic. The M1 and M1A1 take 20-round or 30-round box-type magazines; the M3 uses 30-round box-type magazines only.

The M1 and M1A1 have wooden stocks. The M3 is all-steel, with steel skeleton stocks (made from a single piece of formed steel rod) that can be telescoped into the weapon for firing from the hip and for easier carrying. Nothing is wasted in the M3 submachine gun; even the stock ends are drilled and tapped for use as cleaning rods.

Figure 14–14 illustrates the M1 and the M3. The M1928A1 is by far the least common type of submachine gun in the Navy, and will not be taken up here. (If you do come across it, get information on it from Army FM 23–40 and TM 9–1215.) The M1A1 is identical with the M1 except that it has a fixed integral firing pin instead of a movable firing pin and hammer. This section will concentrate on the M1 and M3.

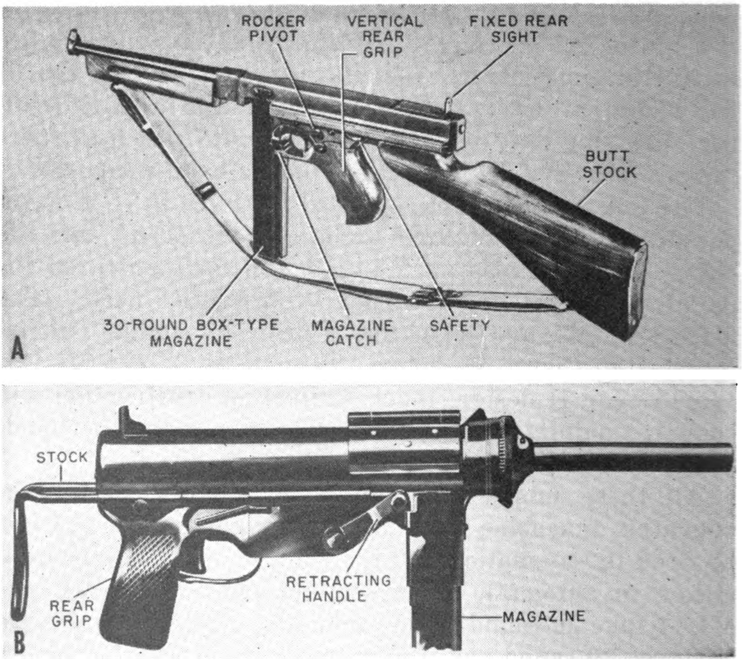


Figure 14–14.—Caliber .45 submachine guns. A. M1. B. M3.

MAIN CHARACTERISTICS OF CALIBER .45 SUBMACHINE GUNS

	M1	*M3*
Length (in.)	31.9	29.8
Weight (without magazine) (lb)	10	8.1
Muzzle velocity (fps)	920	920
Chamber pressure (psi)	12,000 to 16,000	12,000 to 16,000
Length of barrel (in.)	10.5	8
Maximum range (yd)	1,600	1,600
Maximum effective range (yd)	150	150
Rifling twists (in barrel)	1 turn/16 in.	1 turn/16 in.
Trigger pull (lb)	10 to 14	5 to 7
Rate of fire (rd/min)	700 to 800	340 to 450

Operating the M1 Submachine Gun

LOADING. To load the M1 or M1A1 submachine gun, first retract the bolt handle (fig. 14–15) to cock the weapon. Turn the safety (fig. 14–14) to SAFE. Push the loaded magazine up into the groove of the trigger frame until the magazine catch snaps into position.

The weapon can be fired either in semiautomatic or in automatic.

SINGLE FIRE (semiautomatic). Turn the rocker pivot aft to SINGLE and the safety to FIRE. Squeeze the trigger to fire each round, and release the trigger quickly.

FULL AUTOMATIC FIRE. Turn the rocker pivot forward to FULL AUTO and the safety to FIRE. Squeeze the trigger to fire a burst. The gun will continue to fire automatically as long as the trigger is held and there is ammunition in the magazine.

UNLOADING. When the magazine has been emptied, the bolt is automatically held in open position. To close the bolt on an empty chamber, rotate the magazine catch counterclockwise to remove the magazine, then grasp the bolt handle in retracted position, and squeeze the trigger. Let the bolt go slowly forward on the empty chamber.

Functioning of M1 and M1A1 Submachine Guns

Like the 20-mm AA gun, which is also blowback-operated, the M1 and M3 submachine guns fire from an open bolt—that is, the trigger mechanism releases the bolt,

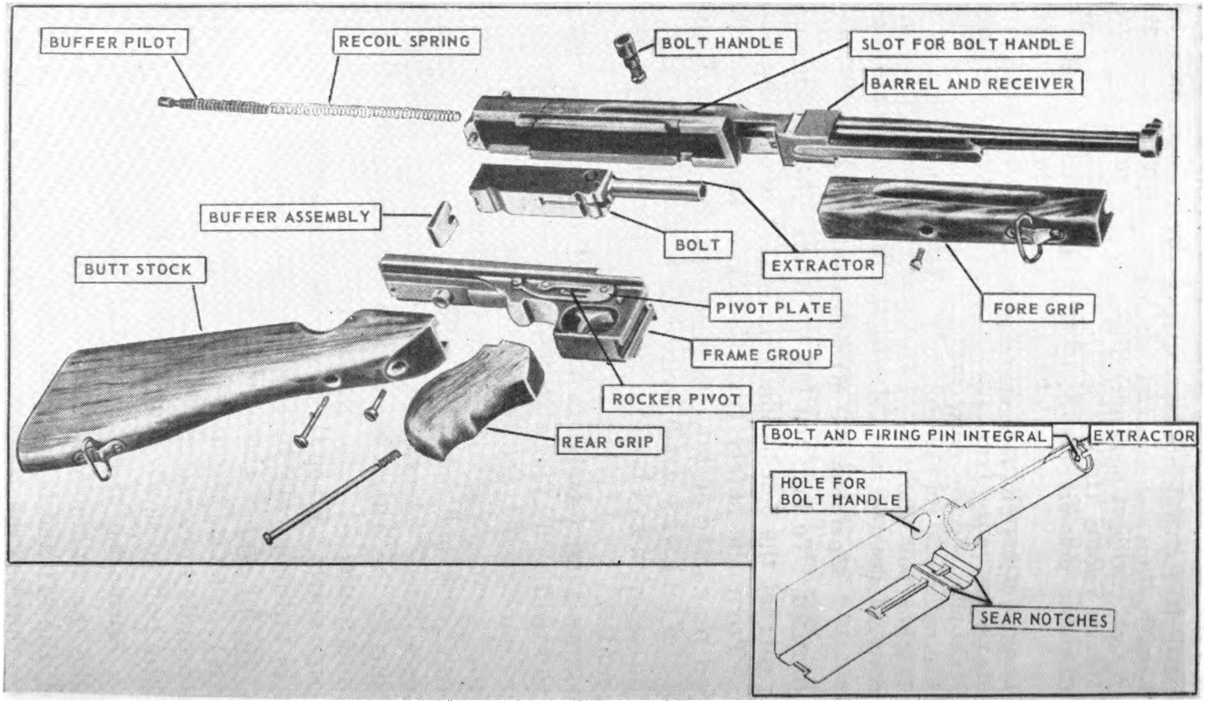


Figure 14—15.—Caliber .45 machine gun M1. Disassembled view of gun. (Inset: M1A1 bolt).

which as it moves forward strips a round from the magazine, rams it into the chamber, and fires it. You can follow most of the details of the M1 submachine gun's functioning from the disassembled view in figure 14–15. For the sake of convenience, we can divide its functioning into two phases—backward movement of recoiling parts, and forward movement of those parts. The recoiling parts include the bolt and the parts attached to it, but not the barrel or any parts of the trigger mechanism.

BACKWARD MOVEMENT. As the cartridge fires, the pressure of the powder gases forces the bolt to the rear against the recoil spring. The extractor holds the empty case against the face of the bolt. After the bolt has traveled to the rear about 2 inches, the ejector throws the case through the ejector opening. The bolt still has about 1¾ inch to go aft before the back of the bolt contacts the buffer. During rearward movement, the bolt compresses the recoil spring and the buffer absorbs the remaining shock. On the bolt underside are two sear notches. If the bolt strikes the buffer, the rear sear notch will pass over the sear and the sear will engage the front notch. If the bolt fails to strike the buffer, the sear will engage the rear notch. (The notches are visible on the M1A1 bolt pictured in the inset of fig. 14–15.)

FORWARD MOVEMENT. When the trigger is squeezed, the sear releases the bolt, which is forced forward by the recoil spring. After moving about 1 inch, the front of the bolt contacts the topmost cartridge in the magazine and pushes it forward and along the bullet ramp in the receiver into the chamber. When the cartridge is seated in the chamber, the extractor engages the rim of the cartridge. Just before the bolt reaches its forwardmost position, the lowest point of the hammer on the underside of the bolt (M1 gun) strikes the receiver, much as in the 20-mm AA gun, causing the hammer to pivot around the hammer pin and strike the head of the firing pin with its upper end. This fires the cartridge.

In the M1A1 submachine gun the bolt face has a raised part (fig. 14–15, inset) which functions as an integral firing pin. It strikes the cartridge primer as the bolt is driven fully forward. This type of bolt has no hammer and separate firing pin.

Maintenance Inspection of M1 and M1A1 Submachine Guns

In addition to routine cleaning and maintenance, inspect the submachine gun M1 or M1A1 annually for operation and functioning, using dummy ammunition. Here is the general procedure:

INSPECTION OF SUBMACHINE GUN AS A UNIT.

1. Check for general appearance, cracks, scratches, rust, or wear. Note if fore and rear grips are firmly attached.
2. Retract the bolt, remove the magazine, and see that the chamber is clear. Grasp the bolt handle and squeeze the trigger, allowing the bolt to go slowly forward on the empty chamber. Note binding or sluggishness in bolt movement.
3. Test magazine catch functioning. Load the magazine with several dummy rounds, attach it to the gun, retract the bolt, set the rocker pivot to either SINGLE or FULL AUTO and the safety to SAFE. Squeeze the trigger. The bolt should remain cocked.
4. Turn the safety to FIRE and squeeze the trigger. The bolt should move forward. Load the dummy cartridge in the chamber and "fire" it. Retract the bolt and check for proper extraction and ejection.

DETAIL INSPECTION OF BARREL AND RECEIVER GROUP.

1. Remove the bolt and spring from the receiver, and inspect the chamber and bore. Use a piece of white paper in the receiver to reflect light into the bore. Rotate the barrel slowly to inspect the whole bore circumference. If the barrel has pits or bulges, it should be replaced.
2. Check the ejector. If it is loose or damaged, replace the receiver.

DETAIL INSPECTION OF BARREL AND RECEIVER GROUP. Examine the bolt. Inspect the sear notch for burs and wear. Check the firing pin (M1) for wear and deformation, and the extractor for set and deformation. Check the recoil spring for kinks, fracture, or lost tension.

DETAIL INSPECTION OF FRAME GROUP . The parts of this group are illustrated in the disassembled view in figure 14–16.

1. Turn the safety to FIRE and the rocker pivot to SINGLE. Squeeze the trigger. The disconnector should lift the front of the sear lever and depress the

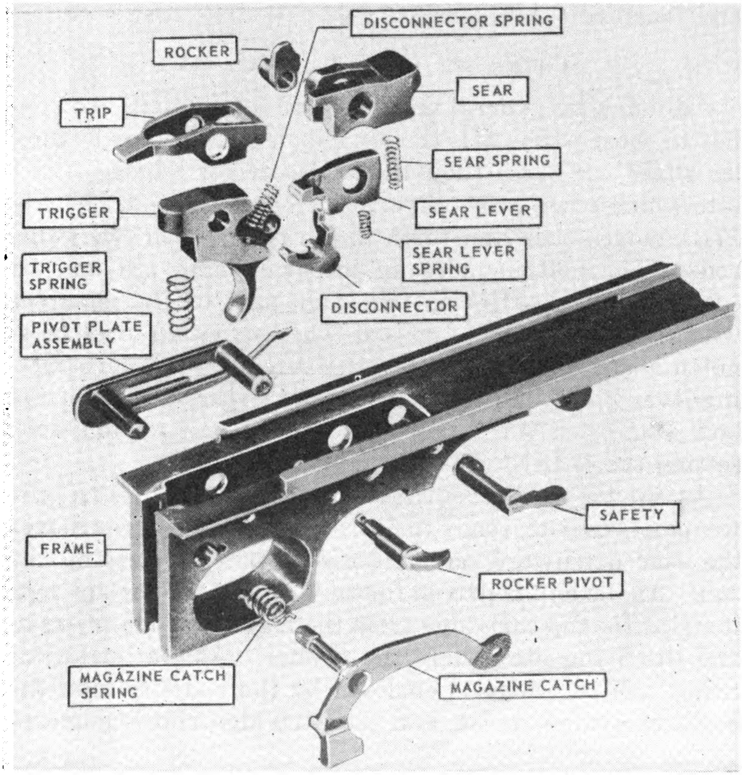


Figure 14–16.—Caliber .45 submachine guns M1 and M1A1. Frame group, disassembled.

nose of the sear. Without releasing the trigger, push the rocker forward. The rocker should disengage the disconnector from under the sear lever. Turn the rocker pivot to FULL AUTO. Squeeze the trigger and hold it. The disconnector should not be disengaged from the sear lever, and the sear nose should remain depressed.

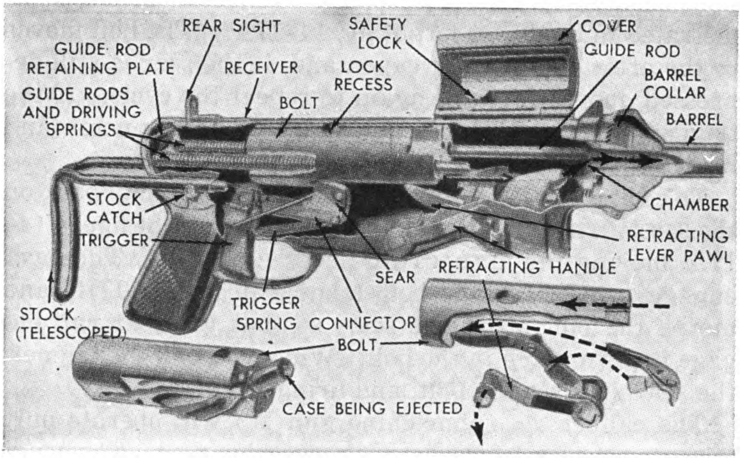
DETAIL INSPECTION OF BOX MAGAZINE. Check box magazine for fit and retention in receiver, and inspect for deformed lips and other damage. Depress the follower; note smoothness of operation and tension of spring. Check follower for deformation and burs, and the spring for set and fracture.

Caliber .45 Submachine Gun M3

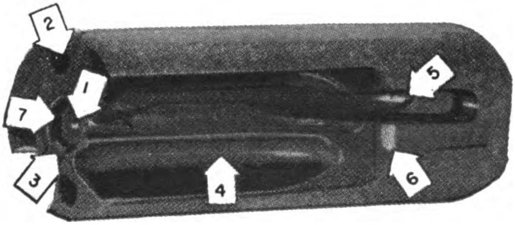
Although its general principles of functioning are similar to those of the M1, the M3 submachine gun is a simpler affair. It has a tubular metal receiver (fig. 14–17A) into which screws the barrel. The one-piece bolt (fig. 14–17B) moves back and forth in the receiver on two guide rods. The bolt includes an integral firing pin and its CARTRIDGE RECESS forms the after part of the chamber when the bolt is fully forward. The retracting-lever pawl notch and the sear notch respectively engage the retracting-lever pawl and the sear. In the upper surface of the bolt (fig. 14–17A) is a recess used in connection with setting the safety. There is no hammer.

As shown in the cutaway view of figure 14–17A, the weapon is cocked, ready to fire. Pulling the trigger moves the sear downward out of the sear notch, releasing the bolt. As the bolt is driven forward by the driving springs, it strips the top cartridge from the magazine, chambers it, and the firing pin strikes the primer. At the instant of firing, the cartridge is enclosed by the chamber and the bolt's cartridge recess, and the cartridge rim is engaged by the extractor.

The mass of the bolt is so great that by the time it retracts enough to open the chamber, gas pressure has



A. Cutaway view. (Lower left shows camming action of ejector on spent case. Lower right shows action of retracting lever and handle in cocking the gun.)



B. Bottom view of bolt.

1. Firing pin.
2. Guide rod bearing.
3. Extractor.
4. Extractor pin.
5. Retracting lever pawl notch.
6. Sear notch.
7. Cartridge recess.

Figure 14–17.—Caliber .45 submachine gun M3.

dropped. The bolt moves backward, with the extractor drawing the expended case out of the chamber. As the case passes over the ejector, it is thrown out of the open port in the top of the receiver. (Ejector action is illustrated in the lower left of fig. 14–17A.) The bolt moves to the after end of the weapon and, if the sear is still depressed, moves forward again to repeat the cycle. If the trigger is released, the sear engages the sear notch and holds the bolt cocked.

To cock the weapon for the first round, you pull back on the RETRACTING HANDLE as in the lower right of figure 14–17A, moving the RETRACTING-LEVER PAWL aft. The pawl engages a notch in the bolt (shown in fig. 14–17B) and moves the bolt abaft the sear, so that the sear can engage its own notch in the bolt. When you pull the trigger, the sear releases the bolt, and firing begins.

The caliber .45 submachine gun M3 will operate only with its cover open to expose the ejection port. The cover is actually the weapon's safety. The weapon is normally carried with bolt forward (uncocked), and cover closed, so that the safety lock (a projection on the cover's underside) engages the LOCK RECESS in the top of the bolt. When so locked, the bolt can move neither forward nor backward.

Closing the cover with the bolt cocked also prevents fire, because the safety lock forces the bolt backward from the sear and holds it there. This is called "locking the piece."

Maintenance Inspection of the Submachine Gun M3

GENERAL INSPECTION. First inspect the weapon as a whole for general appearance and condition, smoothness of operation, and functioning of magazine, extractor, and ejector.

OPERATING TEST. Insert a magazine containing at least eight dummy cartridges and close the bolt. While retracting the bolt, see that the extractor has fully engaged the cartridge and that the ejector throws the cartridge from the receiver. A pull in excess of 23 pounds to cock the gun indicates that the receiver has been dented, that the guide rods are bent, or that the ejector is binding in its slot in the bolt.

Check feeding action. Most failures to feed are caused by defective magazines. Look for dirt or rust in the magazine, weak magazine spring, or dents in the magazine body.

If the weapon fails to extract, look for a worn or broken extractor, an extremely dirty chamber, or a dent under the extractor.

Check trigger pull. It must be greater than 4½ pounds but not over 7½.

BROWNING MACHINE GUN, CALIBER .50, M2

The caliber .50 BMG now used by the Navy and the Army is the M2, which may be equipped with either of two different kinds of barrel—air-cooled (for aircraft use), or heavy barrel (HB). Although it is not used as widely in the Navy as it once was, you may still come across the HB type on certain landing craft. (Caliber .50 MG's are still important as aircraft armament, but you're not likely to have to deal with such installations. And we shall not take up here the air-cooled caliber .50 BMG.)

The mechanisms of the weapon and the principles of operation are very much like those of the caliber .30 BMG that we studied earlier in this chapter. Rather than repeat the same material, we'll concentrate on the differences, without going into elaborate detail. If you need further details, see the Army's FM 23–65 and TM 9–1225.

The main characteristics of the caliber .50 BMG M2 are as follows:

Weight of gun with barrel (lb)	84
Length overall (in.)	65⅛
Length of barrel only (in.)	45
Rifling	
Uniform R. H. twist	1 turn in 15 in.
Lands and grooves	8 ea
Rate of fire (cyclic, rd/min)	500 to 600
Muzzle velocity (approximate, fps)	2,900
Range (approximate, yd)	7,400

Construction of the BMG Caliber .50 HB, M2

Figure 14–18 shows the caliber .50 BMG exterior and in a cutaway view. The cutaway view shows (dotted lines) the bolt latch release, but omits the bolt latch mechanism in the receiver. The construction in general is much like that of the caliber .30 BMG. The breech lock camming arrangements are different, as are the trigger linkage, location of the bolt handle, and other details, but the functioning is much the same. However, the ammunition feed mechanism can be arranged to feed from either side.

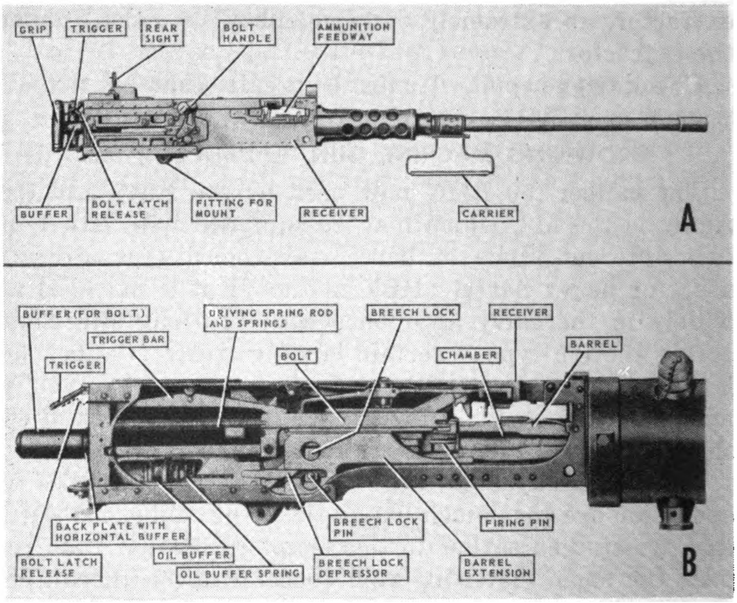


Figure 14–18.—Browning machine gun, caliber .50 HB, M2. A. Exterior. B. Cutaway view.

Note the two buffers. The upper one takes the recoil shock of the bolt, and the lower (oil) buffer takes the recoil shock of the barrel and barrel extension. There is no lock frame in the caliber .50 BMG.

Operating the BMG Caliber .50 HB, M2

You load the belt, half load, load, clear, and unload the BMG caliber .50 much as you do the caliber .30. But there are some differences in the firing controls and how you use them, as can be seen in figure 14–19.

To fire the loaded and cocked gun, you depress the trigger. If the bolt latch is released, the gun will continue to fire automatically so long as the ammunition holds out and the trigger is down.

The bolt latch in the receiver engages the bolt when it is in recoil position. Pressing the bolt latch release (fig. 14–19) causes the latch to release the bolt, which then drives forward and chambers the next round. If you release the bolt latch release lever and depress the trigger, the gun will fire once, and stop with the bolt in recoil posi-

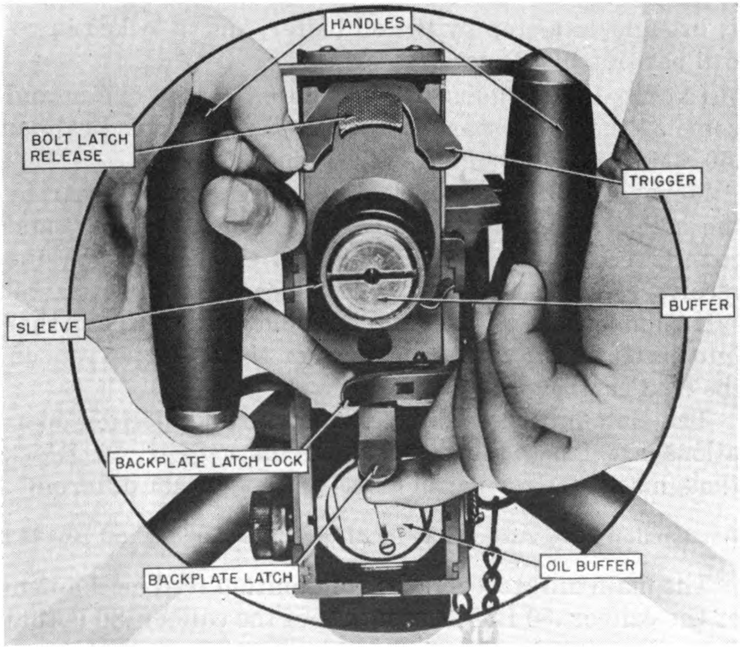


Figure 14–19.—Browning machine gun, caliber .50 HB, M2. Back plate and controls.

tion again. For the gun to fire in full automatic you must hold down the bolt latch release lever. It can be locked down by depressing it, then twisting the knurled sleeve on the buffer, until the lever stays down when released.

NOTE: Caliber .50 BMG's other than HB do not have this bolt latch arrangement.

Functioning of the BMG Caliber .50 HB, M2

You can follow most of the functioning cycle in figure 14–18B. Assume the chamber is loaded, the gun cocked, and the bolt latch released. The gunner depresses the trigger, the firing pin strikes the primer, the propelling charge goes off, and the recoiling parts (same as in the caliber .30 BMG) start rearward. After 1⅛ inch of travel the breech lock is cammed down to release the bolt from the barrel extension, which strikes the accelerator, is brought to a stop by the oil buffer, and is locked in recoil position by the accelerator.

(NOTE: In HB guns there is no oil in the buffer and some of the buffer parts are omitted. Air-cooled caliber .50 BMG's use oil buffers with oil in them.)

Meanwhile, the bolt, kicked all the way to the rear by the accelerator, rebounds against the upper buffer, and counterrecoils, unlocking the barrel extension from the receiver. When the breech lock reengages, the barrel extension locks to the bolt and both move forward together into battery. The cycle repeats when the firing pin sets off the next cartridge.

The ammunition feeding, extraction, and ejection operations are much the same as in the caliber .30 BMG, though some of the mechanisms are somewhat different.

Ammunition Feed Arrangements of the BMG Caliber .50 HB, M2

The main difference in the ammunition feed mechanism of the caliber .50 BMG from that of the caliber .30 is that the caliber .50 can be set up for feeding from either direction. Figure 14–20 shows both setups. Note that the

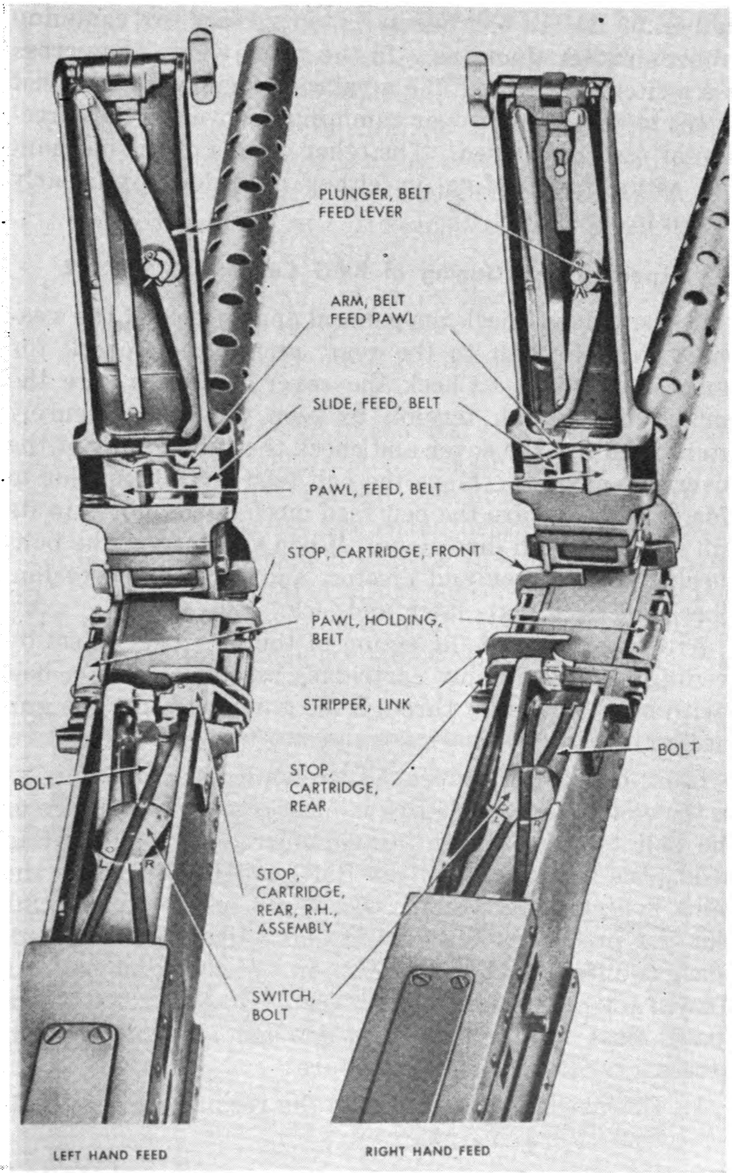


Figure 14–20.—Browning machine gun, caliber .50 HB, M2. Feeding mechanism parts set up for left-hand and right-hand feeding.

caliber .50 BMG's bolt has in its top surface two camming grooves rather than one. In the place where they cross is a switch, something like a railroad switch, which must be set to select the proper camming groove for the direction of feed to be used. The other details of the mechanism setup for feeding in either direction are clearly shown in the figure.

Inspection and Gaging of BMG Caliber .50 HB, M2

INSPECTION. Check the general appearance of the weapon. Pull the bolt to the rear, release, and check for smooth operation. Check the cover latch; be sure the spring has enough tension to keep the cover securely latched. Raise the cover and check the functioning of the cover detent pawl. Move the belt feed lever from side to side, and make sure the belt feed mechanism moves in its full travel in both directions. When you inspect the bolt, check the extractor and ejector, and look for corrosion. Check the back plate latch and lock.

After gaging, test the action of the gun mechanism by feeding several dummy cartridges assembled into a belt (with new belt links) through the gun, operating the gun mechanism by hand.

GAGING. In the caliber .50 Browning machine gun, as in the caliber .30, headspace is measured from the face of the bolt to the base of the chambered cartridge. Bad headspace adjustment in the BMG caliber .50 causes the same symptoms and malfunctions as in the caliber .30. But the procedure for gaging and adjustment of headspace is different in the bigger gun, chiefly in the use of a HEADSPACE AND TIMING GAGE (Army No. A196228). Headspace must be checked before firing, and adjusted, if necessary. Here is the procedure:

1. Retract fully, then release the recoiling parts. This cocks the firing pin.
2. Retract the bolt slightly (not more than 1/16 in.) to relieve the thrust of the driving spring between

the bolt and the after end of the barrel. The forward face of the breech lock and the bolt should be in close contact, as in firing.

3. Pull up the extractor. Insert the gage in the T-slot between the face of the bolt and the after end of the barrel (fig.14–21). If headspace is too tight, the gage won't go in. If headspace is correct or too great, the gage will slip in easily.
4. If the gage doesn't go in on the first try, unscrew the barrel ONE notch, and try the gage again. Repeat, if necessary, until it does go in. The adjustment is then correct.
5. If the gage does go in the first time, screw the barrel IN one notch, and try again. If the gage no longer goes in, restore the first position of the barrel; this is the proper adjustment. If the gage still slips in, screw the barrel in another notch, and repeat. The proper adjustment is the one in which the barrel is screwed in as far as it can be without making the headspace too tight.

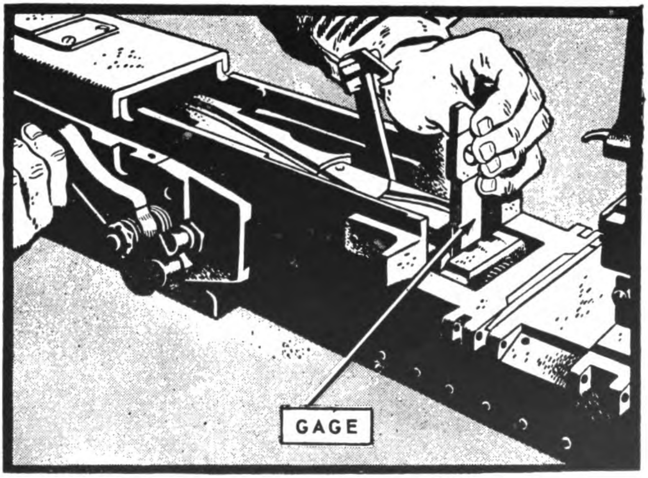


Figure 14–21.—Browning machine gun, caliber .50 HB, M2. Headspace gaging.

SUMMARY

In this chapter we studied in some detail the construction of the main types of the small-arms ammunition with which you are concerned. We then took up the small-arms automatic weapons that you are expected to know—the Browning automatic rifle, caliber .30, M1918A2; the Browning machine gun, caliber .30 M1919A4; the Thompson submachine guns, caliber .45, M1 and M1A1, and the M3; and the Browning machine gun, caliber .50 HB, M2. We studied the structure, functioning, and operation of each of these weapons, and described the principal maintenance inspection and gaging operations for each. (You are, of course, also expected to know about their routine upkeep, lubrication, cleaning, and before-firing and after-firing care, but these you can study in the preceding course in this series.)

QUIZ

In the following questions, select the one BEST answer.

1. Rimfire cartridges are so called because they
   a. have rims larger in diameter than the cartridge case
   b. have the primer composition distributed around the rim
   c. are now made only in caliber .22
   d. require no separate primer structure
2. In a centerfire cartridge, the firing pin strikes the
   a. primer cup
   b. primer anvil
   c. cartridge rim
   d. primer pocket
3. Except for caliber .45 ammunition, the exterior surface of a jacketed bullet is always composed of
   a. gilding metal
   b. lead
   c. lead hardened with antimony
   d. steel
4. All the dummy ammunition described in this chapter can be identified by
   a. absence of the bullet
   b. tinning on the cartridge case
   c. absence of markings on the bullet point
   d. holes in the cartridge case
5. The Navy's 12-gage riot-type shotguns use ammunition loaded with No. 00 buckshot. Which of the following statements about this ammunition is true?
   a. Each shell weighs 1⅛ ounce
   b. Each shell contains 9 balls
   c. The shell is .34 inch in diameter
   d. Each ball weighs 26 grains
6. Gas pressure acts on the operating mechanism of the BAR
   a. while the bullet travels the last six inches of the barrel
   b. during the full rearward motion of the slide
   c. when the gas passes through the port holes in the gas cylinder tube
   d. from the instant the propelling charge fires until the bullet leaves the bore
7. In the BAR the sear release cams the sear down only when
   a. the trigger is retracted and the rifle is firing at normal rate
   b. the trigger is released and the rifle stops firing
   c. the trigger is retracted and the rifle is firing at slow rate
   d. the trigger mechanism is set at SAFE

8. Which of the following caliber .30 BMG components moves aft the furthest in recoil?
   a. Barrel
   b. Barrel extension
   c. Lock frame
   d. Bolt
9. When you HALF LOAD the caliber .30 BMG,
   a. the first round is chambered, and the gun can be fired
   b. the first round is chambered, and the gun is set at SAFE.
   c. the first round is in the T-slot of the bolt, but the gun is not ready to fire
   d. the first round is in the extractor, but the gun is not ready to fire.
10. Which of the following parts of the caliber .30 BMG mechanism causes the accelerator to unlock the barrel extension?
    a. The breech lock cam
    b. The bolt
    c. The extractor
    d. The camming surfaces on the front projections of the lock frame
11. To set the M3 submachine gun at safe:
    a. Retract the retracting lever
    b. Move the safety to the rear
    c. Close the cover
    d. Is impossible, because the weapon has no safety
12. In the caliber .50 BMG HB, M2, the bolt latch mechanism
    a. holds the bolt in full recoil position until released
    b. functions only as a safety
    c. latches the bolt and barrel extension
    d. permits semiautomatic fire only when set to keep the bolt disengaged

CHAPTER 15

MAINTENANCE

INTRODUCTION

What is Maintenance?

If you had to sum up in just one word the main job of the Gunner's Mate, you could do worse than to select the word that makes up the title of this chapter. One of the main purposes of this course, and of your technical training generally, is to prepare you to do your maintenance job effectively.

Maintenance work can be considered as falling into three more or less distinct kinds of activity—UPKEEP, REPAIRS, and ALTERATIONS.

UPKEEP in general includes the operations you find in check-off lists—lubricating, inspecting, adjusting, exercising, painting, testing, corrosion-proofing, and so on.

REPAIR includes troubleshooting, replacing, and restoring equipment or parts to serviceable condition after there has been a material failure or malfunction. It makes no difference what has caused the failure, whether it is wear, rust or corrosion, accident, personnel error, failure of some other part or equipment, or enemy action.

But repair does NOT include any change you may make to improve a piece of equipment over its original design. Such a change is an ALTERATION. Navy ordnance gear may not be altered except with the approval of the Bureau of Ordnance.

What This Chapter Covers

To do any kind of maintenance work on your equipment, you've got to know it—well. One way to learn about it is to study the hardware itself. It's a good way, too, and there's really no substitute for it. But you'll learn faster, and you'll learn more, by using also certain source materials. This course textbook is such a source; so are the OP's and OD's and other publications you've seen references to in it. But there's one other kind of source material for this information. In many ways, it's the most valuable. That's why the first part of this chapter is concerned with ORDNANCE DRAWINGS.

In the rest of the chapter we'll take up other paperwork entailed in ordnance maintenance operations, and finally we'll go into some common maintenance work that you'll find worth knowing no matter what kind of ship you're assigned to.

ORDNANCE DRAWINGS

All manufacturers of ordnance equipment make drawings of all ordnance equipment that they manufacture. Copies of these drawings, reproduced by blueprinting, the ozalid process, or in some other way are supplied to every naval ship or installation that has the equipment or for some other reason requires copies or PRINTS of the drawings. Many drawings are also reproduced in OP's and other technical manuals. Many of the drawings you'll see are made by the Bureau of Ordnance or the Naval Gun Factory, but many others are made by the contractors who manufacture the equipment for BuOrd. In any case, ordnance drawings are all set up similarly.

Types of Drawings

Drawings differ, depending on their purposes. The main types of drawings, as classified according to purpose by BuOrd, are:

1. GENERAL ARRANGEMENT DRAWINGS. This kind of drawing shows the complete equipment, assembled.

It indicates general appearance and relationships of important component assemblies, and identifies the drawings that describe the components of the equipment.

2. INSTALLATION DRAWINGS. These show such features as mounting pads and brackets, shock mounts, points for entrance of cabling and mating mechanical parts, type of cable required, dimensions of mounting hardware needed, and directions for how to orient the equipment and secure it to its place on bulkhead or deck. One variety of this type of drawing, called an OUTLINE DRAWING, shows overall dimensions and clearances required for operation and servicing of equipment. These drawings may also give such vital statistics on the equipment as weight, ventilation required, the degree to which the equipment enclosure is protected against spray and dust, and so on.
3. ASSEMBLY and SUBASSEMBLY DRAWINGS. These show the constructional details of the assemblies of which the complete equipment is made up. In general, you can think of an assembly (or subassembly) as any group of two or more parts assembled to make up a unit. Assemblies, of course, may incorporate subassemblies. The words assembly and subassembly are sometimes used pretty loosely, but the idea is plain enough. In any case, an assembly drawing is intended to enable a properly equipped shop to make up the finished assembly from the prescribed parts and assembling and finishing materials. Along with the BILL OF MATERIAL (usually a part of the drawing) it shows what materials and parts, how many of each, and what sizes and types go to make up the complete assembly. It also shows dimensions, and references to other drawings.
4. DETAIL DRAWINGS. When you disassemble any piece of equipment far enough, you eventually get down to individual pieces that cannot be disassembled any

further. These are represented by DETAIL DRAWINGS, which give all the information that a properly equipped shop will need to make the piece exactly as required. The details are assembled, of course, to make the subassemblies and assemblies that make up the completed equipment.

5. WIRING DRAWINGS. The main purpose of a wiring drawing or diagram is obvious from its name—it shows you how to wire a piece of equipment, or a system. There are several varieties of wiring diagrams.

An EXTERNAL wiring diagram shows how to connect an item of equipment to the ship's wiring system or to other pieces of equipment. It shows terminal boards, binding posts, plugs, jacks, and other connection points and devices, and identifies them by letters and numbers. Lines denote the electrical conductors to be installed. The drawing shows the size and type of wire to be used; the kind of insulation, shielding, duct work, and armoring specified, as applicable; lengths needed; where ground connections are to be made; where joints must be soldered, welded, or clipped; and so on. And it specifies the kind of current (d-c or a-c, and frequency) and voltage for each conductor.

An INTERNAL wiring diagram does the same for wiring inside an equipment. It also identifies and shows where the fuses are, the size and type to be used, and their circuits. It locates, and identifies with standard symbols, all lamps, motors, synchros, resistors, capacitors, transformers, chokes, switches, relays, and all other electrical components in the equipment, and gives their electrical values, as applicable. It identifies all the terminals and connection points. This is one of the most useful kinds of drawing for electrical maintenance and troubleshooting.

An ELEMENTARY wiring diagram is about halfway between the diagrams we've just discussed and the SCHEMATIC to be taken up shortly. It shows terminal and connection points, component locations and values, and so on, but it also is arranged so that it's much easier to follow and understand the circuit than with the usual wiring diagram. But note that the elementary, like the pure schematic, has little respect for the actual sizes and shapes of parts or equipment, or for their physical location or orientation. The traceability of the circuit is a much more important consideration. On elementaries, by the way, you'll generally find (though it's not often stated in so many words), that broken or dashed lines (----) indicate mechanical connections, while the solid lines (————) denote electrical connections.

ISOMETRIC wiring diagrams show the routing of cables in a large installation.

6. SCHEMATIC DRAWINGS. About the only general statement you can make about schematic drawings or diagrams is that their primary purpose is to help the user understand the functioning of the equipment. Electrical schematics are commonest, but you also see schematics of hydraulic systems, pneumatic systems, and even such things (though you're not likely to have to use them) as the flow of papers being processed through an office. Schematics often have very little to do with the actual physical appearance or construction of the equipment diagrammed.

Relatively few of the actual engineering drawings you use are likely to be schematics, though you find them in a great many other places—such as this book, which has a number of them. But one type of schematic that you'll find very helpful in understanding and tracing the functioning of moving—especially rotating—mechanical components is the MECHANICAL SCHEMATIC or GEARING DIAGRAM. When they appear as BuOrd drawings, such diagrams have such information as pitch and number of gear teeth on a gear, functions of cams, connections between electrical and mechanical devices (such as switch contacts operated by cams), and a great deal more. You can get EXACT information on equipment mechanisms from a gearing diagram—something that other types of schematics often give only in an approximate way, if at all. We'll go into further detail on this important type of drawing in the next few pages.

7. LUBRICATION DRAWINGS. A lubrication drawing or chart for naval equipment is often a general arrangement drawing, or a group of them showing several views, in which lubrication fittings and other points are called out by labels. Some aeronautical, Army, and commercial equipment (particularly automotive) may have special pictorial or line drawing charts made up especially to serve for lubrication guidance. The OP on every equipment normally has a lube chart in its appendix.
8. TOOL DRAWINGS. Drawings of special tools (you don't ordinarily have much need for drawings of common tools) such as spanner wrenches for specific marks and mods of guns, or such special tools as extractor trip devices for 5"/38 mounts, are described in drawings—usually assembly or detail type. Such tools are always listed in the OP.
9. SKETCHES. BuOrd recognizes two kinds of sketches —LINE SKETCHES and INDEX LISTS.

LINE SKETCHES are made up and treated much as regular engineering drawings are. The main distinction between them and engineering drawings is that sketches apply to experimental or preliminary ordnance work. You won't usually have much to do with this kind of sketch in connection with the equipment you'll ordinarily work with, though you might come across them in certain activities that work with such material—such as OpDevFor, Naval Ordnance Laboratory, or the Bureau of Ordnance itself. The numbers that identify sketches include the designator SK.

The term INDEX LIST is a general name that includes a number of different types of lists of drawings. One type, the List of Drawings or LD, is discussed in further detail below. Others are:

Index to Lists of Drawings. This is the same as the Master List of Drawings, discussed below.

Index to Assemblies. This is a tabulation of all the assemblies of some type of ordnance gear—for example, all 5-inch dual-purpose mounts. Ship Index. This is a tabulation of ships carrying some one type of assembly.

Torpedo Index. This is a tabulated index of drawings that comprise a complete torpedo design.

10. LISTS OF DRAWINGS (LD's). A List of Drawings, as mentioned above, is considered by BuOrd to be a variety of sketch. In itself, this detail of classification isn't especially important in your job, but it's worth remembering that an LD looks like and is treated like a kind of engineering drawing rather than like a publication.

LD's are in a sense the key to the drawing system used by the Bureau of Ordnance. Beginning at the top of the system, a MASTER LIST OF DRAWINGS or Master LD is prepared for each major ordnance equipment (such as a gun mount or turret). This list includes all components of the equipment concerned. Each component is itemized by assemblies, subassemblies, and details on a separate LD.

The identifying number for each component LD is given, together with the general arrangement drawing number, on the master list of drawings for the equipment. Each component list of drawings also shows the special tools required for servicing that component. By reference to the list of drawings and the drawings for the mark and mod of a given assembly or subassembly, it is possible to work down to an individual part and to identify the correct nomenclature, drawing, piece number, design dimensions, tolerances, and all other necessary information.

How You Use Drawings

When we refer to a "drawing" or "engineering drawing" without qualification, we usually refer to an assembly, subassembly, or detail drawing. Such drawings, as we have seen, explain how to manufacture some part or assembly. And they are also a valuable guide for you in overhauling and repairing the equipment. These drawings are valuable not only because they show how the parts fit (though this is very important itself), but also because they describe and enumerate the fastening hardware you need to put the assembly together (including EXACTLY the proper bolts, nuts, patent fasteners, pins, and so on). And they also show the minor but essential parts that the assembly must have so that it will continue to function as the designer intended it to. A watertight enclosure will leak if it hasn't exactly the gasket called out in the drawing; screws will loosen if they haven't been assembled with the proper lock washers specified in the drawing; and nuts will work free if they haven't been secured with the cotter pins listed in the drawing.

The other types of drawings are equally valuable. General arrangement drawings are good references for the exact nomenclature of major units and as guides to drawings on component assemblies. Installation and outline drawings contain just the information on clearances and dimensions that ship's personnel require when a new piece of equipment is to be installed, and they show how to arrange the piping and wiring to be connected to it. External wiring diagrams show just how to hook equipment into the ship's wiring; after installation, they help in troubleshooting for faulty circuits and malfunctioning components, and in electrical alignment of synchros and other data transmission devices. Internal wiring diagrams are equally valuable for making circuit checks in case of trouble in the equipment. Elementaries are helpful in training personnel, and can be used in circuit checking too. And LD's are valuable for guidance in tracking down through the maze of drawings the particular piece of information you may be looking for.

Every ship carries copies of drawings on its equipment, in the form of blueprints and photoprints. These copies are assembled into sets, each set covering one item. Photoprints are usually bound in books. Aboard ship, both blueprints and photoprints are called "ordnance drawings."

These drawings will be available to you. You'll find them either in a special file in the repair shop, or in the custody of your department head. Make use of them; they'll help you to become familiar with the ordnance you will overhaul. (Remember, when you handle them, to treat confidential drawings as you would any other confidential publication.)

Down in the lower right-hand corner of each drawing you'll find a number. That's the "drawing number." On each detail that's pictured in the drawing, you'll find another smaller number. These are the "piece numbers." These numbers identify both the hardware and the drawing. Sometimes you'll find a letter after the piece number; that shows how many times that piece has been changed or modified since the original design.

Every part of every ordnance device (unless it's very small) has its drawing and piece number stamped on it. The first number is the drawing number; the second is the piece number. For example, you'll find numbers like 120460–2. Read that: drawing number 120460, piece number 2.

Look for these numbers, and use them. Refer to them when you report on a particular piece, or when you order new parts.

Mechanical Schematics (Gearing Diagrams)

One type of drawing that you'll find especially valuable is, as we've already mentioned, the mechanical schematic or gearing diagram. It's worth some special attention here because you often have to use such diagrams, and you should be able to extract from the kind of EXACT information we referred to a couple of pages back.

Let's use as an example a schematic diagram (fig. 15–1) of part of the mechanism that introduces the value of own ship's speed into a rangekeeper. As we analyze this schematic, remember that it isn't intended to show the relative sizes and shapes or spatial relationships of the parts concerned; it's designed to show HOW THE MECHANISM WORKS.

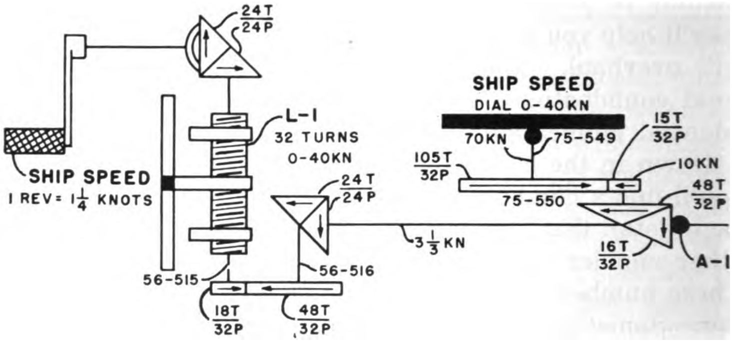


Figure 15–1.—Mechanical schematic.

Now let's trace through the diagram. We begin with the crank, at the left of the diagram. The straight line extending to the right of the crank represents its shaft. The shaft is connected to two triangular symbols; these are miter gears. Those numbers on the gears (24T over 24P) mean that each gear has 24 teeth and a 24 pitch (24 teeth per inch). The miter gears are connected, by another shaft, to a screw-and-nut mechanism. This is a limiting device; it stops the mechanism when it reaches its limit of movement in either direction.

The small rectangle (marked 18T over 32P) is a spur gear. The longer rectangle beside it is another gear that meshes with it. (Notice that throughout the mechanism all pairs of gears that mesh have the same pitch.) This second spur gear is connected through another pair of miter gears, to the shaft marked 3 1/3 KN. From that shaft, the turning force passes to another set of bevel gears, then to another set of spur gears, and finally to the speed indicator dial.

To make the dial read 40 knots, how many times will you have to turn the crank? The schematic drawing gives you all the information you need in order to find out.

Here's the rule for finding gear speed ratio: Divide the product of the number of teeth on all the DRIVING GEARS by the product of the number of teeth on all the FOLLOWING GEARS. For this gear train, we get:

$$\frac{24 \times 18 \times 24 \times 16 \times 15}{24 \times 48 \times 24 \times 48 \times 105} = \frac{1}{56}$$

That means it takes 56 full turns of the crank to move the speed indicator dial through one complete revolution.

Look at the screw in the limiting device. It's marked 32 TURNS, and 0–40 KN. That means two things: Its limit of travel is 32 turns; and while it's moving between its limits of travel, the dial indicator will move between 0 and 40 knots.

You know that the speed reduction ratio between the crank and the dial is 1 to 56. And you can see that the ratio between the crank and the screw is 1 to 1. Since the screw can make only 32 turns, it isn't possible to turn the indicator dial through a complete revolution. To make the dial indicate 40 knots, you have to turn it through only $\frac{32}{56}$ of a revolution. If you COULD turn it through a full revolution, it would indicate

$$\frac{56}{32} \times 40$$

knots, or 70 knots. The drawing gives you that information, under the dial.

Look at the small spur gear near the right-hand edge of the diagram. It's marked 10 KN, meaning that the dial will register 10 knots when this gear turns through one revolution. Let's check. The larger spur gear makes one complete revolution for 70 knots. (You know that because it's directly connected, by its shaft, to the dial.) The larger spur gear of this pair has 105 teeth; the smaller one has 15 teeth. For a full turn of the smaller gear, the dial will move

$$\frac{15}{105} \text{ x } 70 \text{ knots, or } 10 \text{ knots.}$$

In the same way, you can find the relative speed of any gear or shaft in the mechanism. Look at the long shaft marked 3 1/3 KN. Check that and see if it's right.

The diagram (still fig. 15–1), shows something else: the direction in which each gear shaft turns. The arrow on the crank shows that, when you're looking at the crank from the outside of the mechanism, you turn it counterclockwise to advance the dial. The arrow on each gear symbol shows the direction that gear turns when you turn the crank counterclockwise. As you can see from the arrow on the big spur gear, the dial also turns counterclockwise.

There are a couple of symbols in figure 15–1 that we haven't explained. The symbol between the crankshaft and the first miter gear means you can open the connection at that point; the crank is connected to the gear train only when you want it to be. The symbol marked A-1, in the lower righthand corner of the diagram, means there's an adjustment mechanism at that point.

The symbols in schematic diagrams aren't standardized. But their meaning is usually apparent. When it isn't, the symbols are explained on the face of the drawing.

References on Drawings

We're not going to go on to discuss in full detail how to read other kinds of schematics of assembly and detail drawings. For elementary information on the theoretical background of drafting, on how to read drawings of all types (including other kinds of schematics), how to make them, what you can find out from the title box, standard sizes of drawings, and the like, see the basic course *Blueprint Reading and Sketching,* NavPers 10077-A. For more advanced material, official standard abbreviations and symbols, standard conventions, and so on, see the BuOrd publications OP 599 and OSTD 599. The *Bureau of Ordnance Manual* also has a section on drawings. If you are interested in the techniques of drafting, you may want to look up the Navy training courses for Draftsmen. But with mastery of the basic course *Blueprint Reading and Sketching* and the material presented in this chapter, you are adequately armed to deal with ordnance drawings so far as your job as a GM2 is concerned.

ORDNANCE PAPERWORK

The Gunner's Mate's rating isn't one you ordinarily associate with paper-pushing. Yet, though on the whole there isn't a great deal of it, the paperwork you have to do is pretty important. You're expected to know what paperwork you're responsible for, and you must know how to do it.

In addition to what you've learned as a GM3, as a GM2 you're expected to be able to prepare a WORK REQUEST. This requires a little background in the Navy's maintenance system for ships, and we'll go over the main points of this now.

Naval Ship Maintenance System

Most maintenance work on your ship is accomplished by the SHIP'S FORCE—the naval personnel on the ship. But periodically your ship is assigned a TENDER AVAILABILITY or YARD AVAILABILITY. This means that your ship can tie up to a tender or go into a yard for a specified period and have work done that is beyond the capacity of the ship's force or that cannot be done while the ship is operational. Such work is major repair or overhaul of hull, superstructure, machinery, or armament, for which the ship's force hasn't either the tools or the skills. Examples of such work on gunnery department installations are substitution of a new main-battery director for an old one, or lifting out a 5"/38 twin mount to replace parts of the training circle or roller path.

Your department head and leading Gunner's Mate keep track of all maintenance work on the ship's ordnance gear through check-off lists, logs, the CSMP, and the Ordnance Machinery History. You already know something about check-off lists and logs. The Ordnance Machinery History is a compilation in a card file of past equipment operation (including casualties) and present condition, made up from the logs. Every piece of gear installed on the ship is included in the machinery history. But the source of primary importance for scheduling yard and tender work is the CSMP.

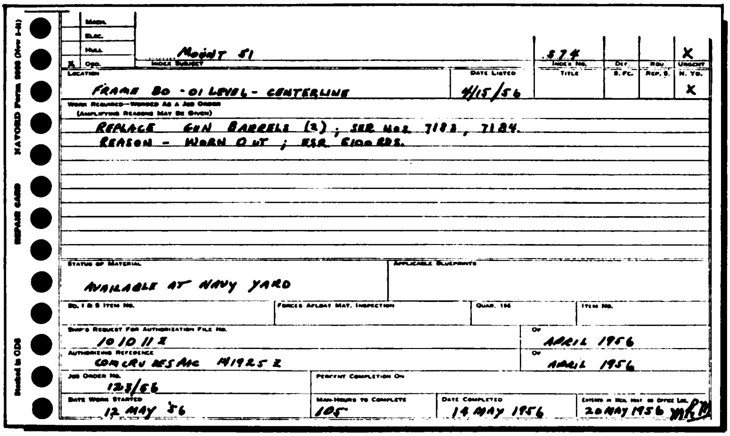
The CSMP

The letters CSMP stand for CURRENT SHIP'S MAINTENANCE PROJECT. You might call this the FUTURE ordnance machinery history. It details, equipment by equipment, the work that needs to be done. Unlike the machinery history, only those equipments are listed in CSMP that actually require work to be done on them.

Physically, the CSMP is a file of card forms about 4 x 6½ inches. There are two kinds of forms—Ordnance Repair Cards (NavOrd form 2033) and Ordnance Alteration Cards (NavOrd form 2034). (See fig. 15–2.) The repair cards describe needed repairs, with one repair item per card. The alteration cards deal similarly with alterations. The CSMP lists ALL repairs and alterations, not just the ones that are too big for the ship's force. From these cards you make up the work requests which ultimately go to the yard or tender.

Preparation for Yard or Tender Availability

But before you make up the work request there's a great deal of other preparation. Yard and tender availabilities aren't an every-Monday-and-Thursday affair. Submarines and attack carriers, for example, ordinarily will run about two years between overhauls. This means that EVERY big repair and alteration job MUST be taken care of during the availability period. Shipyards and tenders



NAVORD Form 2068 (New 1-51) REPAIR CARD

Stocked in ODS

Mach.
Elec.
Hull
X Ord.

Index Subject: MOUNT 51

Index No.: 574

Title:

Def. S. Fc.:

Rou Rep. S.:

Urgent N. Yd.: X X

Location: FRAME 80 - 01 LEVEL - CENTERLINE

Date Listed: 4/15/56

Work Required—Worded As a Job Order (Amplifying Reasons May Be Given):
REPLACE GUN BARRELS (2); SER NOS. 7183, 7184.
REASON - WORN OUT; ESR 5100 RDS.

Status of Material: AVAILABLE AT NAVY YARD

Applicable Blueprints:

Bu. I & S Item No.:

Forces Afloat Mat. Inspection:

Quar. 19:

Item No.:

Ship's Request for Authorization File No.: 101011Z

Of: APRIL 1956

Authorizing Reference: COMCRUDESPAC 141925Z

Of: APRIL 1956

Job Order No.: 123/56

Percent Completion On:

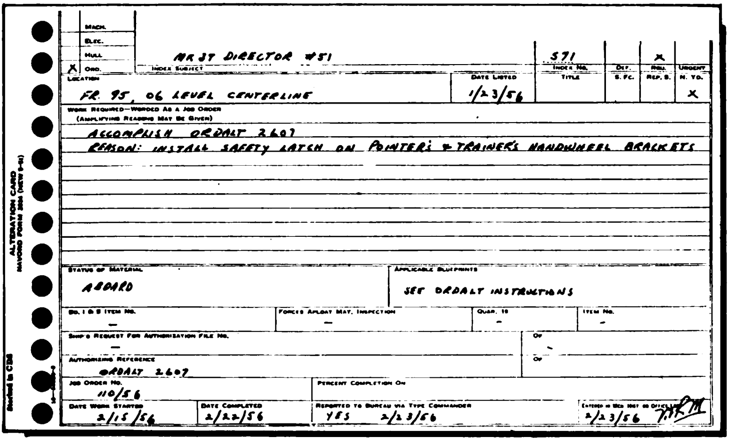
Date Work Started: 12 MAY 56

Man-Hours to Complete: 105

Date Completed: 14 MAY 1956

Entered in Mat. Hist. or Office Ltr.: 20 MAY 1956 MKM

A



ALTERATION CARD
NAVORD FORM 2064 (NEW 9-51)

Stocked in CDS

Mach.
Elec.
Hull
X Ord.

Index Subject: MK 37 DIRECTOR #51

Index No.: 571

Title:

Def. S. Fc.:

Rou Rep. S.: X

Urgent N. Yd.: X

Location: FR. 95, 06 LEVEL CENTERLINE

Date Listed: 1/23/56

Work Required—Worded As a Job Order (Amplifying Reasons May Be Given):
ACCOMPLISH ORDALT 2607
REASON: INSTALL SAFETY LATCH ON POINTER'S & TRAINER'S HANDWHEEL BRACKETS

Status of Material: ABOARD

Applicable Blueprints: SEE ORDALT INSTRUCTIONS

Bu. I & S Item No.: —

Forces Afloat Mat. Inspection: —

Quar. 19: -

Item No.: -

Ship's Request for Authorization File No.: —

Of: -

Authorizing Reference: ORDALT 2607

Of:

Job Order No.: 110/56

Percent Completion On:

Date Work Started: 2/15/56

Date Completed: 2/22/56

Reported to Bureau via Type Commander: YES 2/23/56

Entered in Mat. Hist. or Office Ltr.: 2/23/56 TKM

B

Figure 15—2.—CSMP cards. A. Ordnance Repair Card. B. Ordnance Alteration Card.

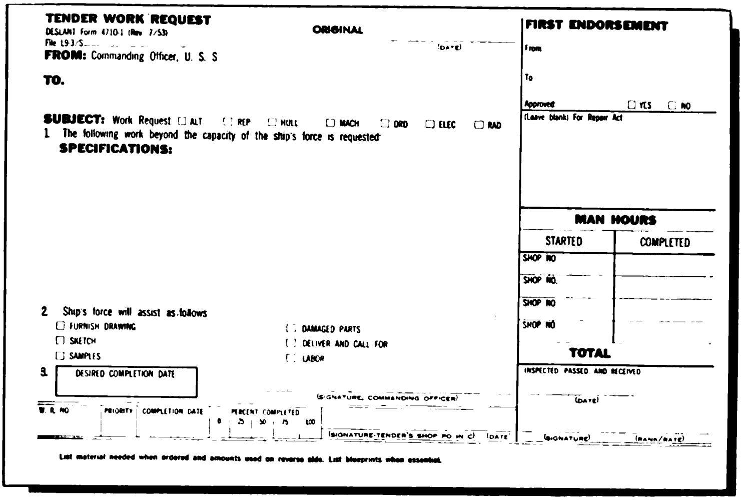
are busy places and always have plenty of work. Once the availability period is over, your ship can't come back a day or two later because some job wasn't completed and was overlooked in the hubbub.

So a good deal of careful preparation is necessary well in advance. One part of this preparation is the inspection by the Navy's highest inspection authority—the Board of Inspection and Survey. This Board conducts acceptance inspections and trials of new ships. It also inspects active ships every three years to determine the state of their maintenance, and it recommends any alterations it thinks necessary. And there are other inspections, such as the arrival inspection made by yard engineers whenever your ship arrives at a naval shipyard for overhaul.

But the main part of the preparation burden rests on your ship's personnel. This begins with compilation of a work list. The work list is made up of work requests, which in turn are compiled from CSMP cards. These work requests are not the ones that actually go to the shipyard or tender. They are rough drafts that you write concerning the equipment you're responsible for. They should include not only work requiring yard or tender assistance, but also jobs that, while within the capabilities of ship's force, require deactivation of the equipment for more than a day or so. In every case, each request should clearly (though briefly) identify the equipment concerned, state the EXACT nature of the work required, indicate just what aspects of the job are beyond the skill or tools of ship's personnel (that means you and the men working with you), indicate how urgent the work is, and give your best estimate of the time required in man-hours.

Figure 15–3 illustrates a final draft work request, and shows the kind of information needed to make it out.

Your division officer gets the requests, and from them your gunnery officer compiles a work list. About six weeks before the ship arrives at the yard or tender, the engineering officer holds a conference of department heads, and at this conference your gunnery officer gets his



TENDER WORK REQUEST
DESLANT Form 4710-1 (Rev 7/53)
File L9-3/S
ORIGINAL
(DATE)
FROM: Commanding Officer, U. S. S

TO.

SUBJECT: Work Request ☐ ALT ☐ REP ☐ HULL ☐ MACH ☐ ORD ☐ ELEC ☐ RAD
1 The following work beyond the capacity of the ship's force is requested:
SPECIFICATIONS:

2 Ship's force will assist as follows
☐ FURNISH DRAWING
☐ SKETCH
☐ SAMPLES
☐ DAMAGED PARTS
☐ DELIVER AND CALL FOR
☐ LABOR

3. DESIRED COMPLETION DATE

(SIGNATURE, COMMANDING OFFICER)

W. R. NO	PRIORITY	COMPLETION DATE	PERCENT COMPLETED				
			0	25	50	75	100

(SIGNATURE-TENDER'S SHOP PO IN C) (DATE)

List material needed when ordered and amounts used on reverse side. List blueprints when essential.

FIRST ENDORSEMENT
From
To
Approved ☐ YES ☐ NO
(Leave blank) For Repair Act

MAN HOURS

STARTED	COMPLETED
SHOP NO	
SHOP NO.	
SHOP NO	
SHOP NO	

TOTAL

INSPECTED, PASSED AND RECEIVED
(DATE)
(SIGNATURE) (RANK/RATE)

Figure 15–3.—Specimen work request.

requests on the list that will be submitted to the captain, to the type commander, and to the yard or tender. The list includes also the items turned up by the inspections made shortly before the availability period is scheduled to begin.

Five days before the ship is due at the shipyard, estimators and engineers from the yard go over the whole ship for their own preoverhaul inspection, and when the ship arrives at the yard there are conferences between the department heads and the shipyard representatives to determine just which jobs will be done, and how. Or, if the ship has come some distance, the preoverhaul inspection becomes an arrival inspection that is done while the arrival conferences are going on. Similar arrival inspections and conferences take place for tender availability periods.

Your Job During Tender or Yard Overhaul

It should be clear by now that the yard or tender availability period is a time when you can get a great deal of work done that it is impractical or inadvisable to try to do (except in case of emergency) when the ship is fully operational. But you can't use the yard or tender availability as a means of getting others to do your work. Even if requests for such work get by your division officer, gunnery officer, and captain, the yard or tender inspection personnel will spot it. They see ships come and go all the time, they know exactly what to expect, and they know how to deal with it. The most likely result is that ship's force (and that still means you) is going to have to do it anyway—without the technical advice and assistance that the yard or tender would be able to give you. And if your gunnery officer is one of the many that take justifiable pride in the self-reliance of their crews in such matters, such a result is not going to improve your reputation with him.

The assistance you can get from yards and tenders even on ship's-force jobs is worth planning for. The OP on the equipment usually details the special tools required for performing each maintenance, repair, assembly, or disassembly operation, but that doesn't necessarily mean that you're going to have each tool aboard your ship. When you compile the work requests, you should look up the tools required for needed assembly and disassembly in connection with the job, and see what additional equipment you'll need. Then you can plan on getting assistance from the tender or yard. Sometimes their maintenance and repair personnel, being specialists, work up special jigs and tools for specific operations that enable the job to be done in a fraction of the time required with standard tools. You can, if you arrange it properly, take advantage of these, along with expert guidance from yard or tender specialists, during the availability period.

In doing this, be sure to work through channels until you've established contacts on the yard or tender. Then you can (if circumstances permit) become more informal. For example, in naval shipyards the formal line of contact between the yard and your ship is through the engineering officer of your ship and the "ship superintendent" assigned by the yard to your ship during the availability period. The unit in the yard that handles all ordnance jobs is Shop 36. (All naval shipyards have parallel organization and nomenclature of operating subdivisions.) The gunnery department's line of contact to this shop is by way of the gunnery officer, the engineering officer, the ship superintendent, the shopmaster (of Shop 36), and, successively under him, the foreman, chief quarterman, quarterman, leadingman, and ordnancemen. Except for the ship superintendent, who is an experienced naval officer, the others in the shipyard are civilians. You haven't any formal contact with them in the sense that you can tell them what to do or change their orders, but you may be assigned to work with them during the availability period. You can learn a good deal from them, and through your gunnery officer you may be able to establish informal contacts through which you can get assistance with ship's-force jobs.

Tenders are also organized into departments, but the setup is different. Your gunnery officer's contact would be the ordnance repair officer in the tender, and the division heads on your ship have direct contact with the divisions on the tender that they have business with (such as the machine shop, optical shop, fire control shop, and so on). Tender personnel are, of course, all naval personnel, and in general it will be easier for you to establish the informal contacts that you can find so helpful. Just be sure to do it through your leading petty officer.

MAINTENANCE OPERATIONS

Maintenance, like safety, isn't something you can put into a separate watertight compartment and discuss apart from the gear and methods of your job. In this chapter we're not going to try to cover every aspect of maintenance beyond the few general statements that were made at the beginning of this chapter, but in this section we'll take up some gun mount maintenance operations of common application that you don't always find discussed in detail in OP's. And these are operations that are typical of the duties of most Gunner's Mates 2. Many of the operations are taken up elsewhere in this course, and there will be references to the chapter concerned; others are described here, briefly or at length.

The maintenance operations that we take up on this basis include:

Bore erosion gaging.
Decoppering.
Checking power drives.
Checking firing stop mechanisms.
Checking hoists and fuze setters.

Bore Erosion Gaging

The internal ballistics of a gun depend heavily on the state of its bore. You are already acquainted with the routines of inspecting and care of gun bores from small arms to 16-inch guns. And you know also that gun bores require not only inspection but also MEASUREMENT, using special gages.

You are already acquainted with plug gages and how to use them. You have no doubt heard of and probably seen star gages, but we don't study this precision instrument in this course. (See the Navy training course for GM1&C on this.) Here we study a gage intermediate in complexity between the plug gage and the star gage—the BORE EROSION GAGE.

In most modern guns, the effects of erosion on gun performance are rather heavily concentrated in one small ring-shaped area of the bore—the ORIGIN OF RIFLING, located in the tapering FORCING CONE. This area is located about halfway along the tapering section of the barrel that connects the rifled tube with the chamber. This tapering section is called the FORCING CONE, because it is the place where the rotating band is forced into the rifling. Figure 15–4 shows these points in detail.

As the gun is fired time after time, the forcing cone and origin of rifling must take the shock of one rammed pro-

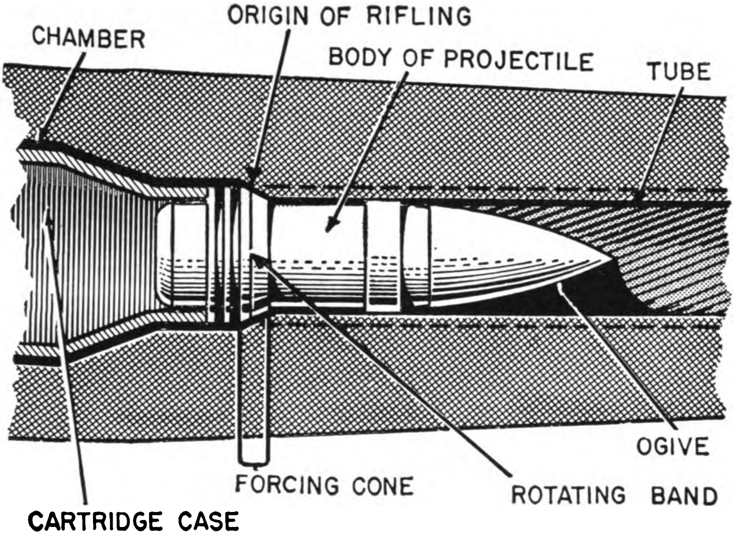


Figure 15–4.—Cross section of gun chamber.

jectile's rotating band after another. Besides that, they are subjected to the high temperatures of burning propellant and to searing blasts of superheated powder gas. So, even though they are of hardened steel, eventually the forcing cone and origin of rifling begin to wear down.

As the wear takes place, rammed projectiles must be pushed further and further up the bore of the gun for the rotating band to engage the rifling. The effect of wear is to move the origin of rifling along the bore toward the muzzle, and thus to lengthen the chamber. By the time this happens, the rifling is likely to be so badly worn that the ballistic performance of the projectile is impaired—a worn weapon loses both accuracy and range. These effects are particularly important in machine guns and small-arms weapons.

It is possible, then, to find out how badly worn a gun is, or to predict its useful life, either by measuring the advance of the forcing cone due to wear, or by measuring the increased length of the chamber.

This kind of measurement is, in fact, applied to small arms and machine guns. In small arms and caliber .30 and .50 machine guns, as you remember, headspace gages are used for this purpose. In 20-mm and larger guns BORE EROSION GAGES are used. In larger weapons, however, other factors also enter into determination of the useful life of the gun. Therefore, the condition of bore and chamber in such guns must also be determined by inspection with boresearching instruments, by star-gaging, and by keeping an accurate record of firing.

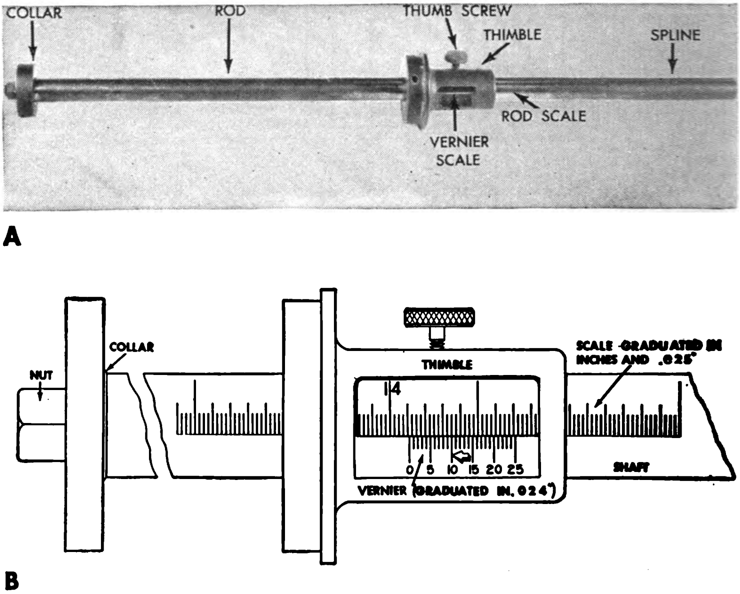


Figure 15–5.—40-mm bore erosion gage.

Now that you know what the erosion gage measures, let us look more closely at the gage itself. The one shown in figure 15–5 is the type used with 40-mm guns.

40-MM BORE EROSION GAGE. The gage is a steel rod about two feet long, with a channel or spline cut along about half of its length. At the forward end (to the left in fig. 15–A) is a circular disc or COLLAR secured by a nut to the rod. A cylindrical THIMBLE can be moved along the rod or shaft and secured at any point by a knurled thumbscrew that protrudes into the channel. Along part of the length of the rod is a SCALE graduated in inches, tenths, and 0.025-inch units. A VERNIER SCALE on the thimble is used with the scale on the rod.

The vernier scale works in principle just like the one described in the Navy Training Course *Basic Machines* (NavPers 10623). It is graduated in 0.024-inch divisions, but you read it as if it were graduated in thousandths (0.001").

You should already know how to read vernier scales through having studied *Basic Machines*. But if you're hazy on it, here's a brief review. Check each step against figure 15–5B. The reading shown in the figure is worked out as follows:

FIRST:—Read inches on the shaft. Figure 15–5B shows this to be .... 14.

SECOND:—Count up the number of 0.025-inch graduations between zero on the vernier and the figure determined in the first step (in this case, 14). In figure 15–5B, there are four of them, which add up to (4 x 0.025 in.) 0.100

THIRD:—Find the line on the vernier scale that matches a line on the shaft scale. In figure 15–5B the matching lines are indicated by a white arrow.

FOURTH:—Read off the matching line on the vernier scale, and add it to the reading in the first and second steps above. In the figure the matching line on the vernier is 10. Added to the values found in the first and second steps, the total reading is 14.110

To use the gage itself to measure 40-mm gun wear, you depress the gun 8° below zero, remove the empty-case deflector, lower the breechblock, open the top and rear doors on the slide, and push the gage in through the rear door and loader. The gage thimble will be accessible through the top door.

Next, insert the collar of the gage into the chamber as far as it will go, until it is firmly and squarely up against the rifling. Then push the thimble forward until it is firmly against the breech face. Tighten the thumbscrew, withdraw the gage, and take the reading in the way already explained above.

Older gages may be too short to be used this way, and it will then be necessary to remove the barrel in order to insert the gage into it.

A new 40-mm gun barrel should have a gage reading between 12.496 inches and 12.540 inches. As the gun wears, this figure increases. A barrel that gives a reading of 15.850 inches or more usually is considered unserviceable and should be replaced.

20-MM BORE EROSION GAGE. The wear gage for 20-mm guns (not illustrated here) is similar to the 40-mm gage in principle. However, it is so calibrated that the serviceability of the gun barrel is directly indicated by the gage. The plug or forward end of the gage fits into the chamber of the gun. On the gage shaft are four marks, respectively 6.4, 6.8, 7.0, and 9.4 inches from the forward end of the plug. Each of the marks stands for a percentage of the remaining serviceable life of the barrel, and to a corresponding loss in muzzle velocity. The following table sets forth this relationship:

Mark (designated by distance in inches from forward end of gage plug)	Approximate remaining serviceable life of the barrel (percent)	Loss in muzzle velocity (feet per second)
6.4	66	15
6.8	33	80
7.0*	20	100
9.4**	0	215

* No longer acceptable for combat service.

** Completely unserviceable.

3"/50 BORE EROSION GAGE. The gage for 3-inch RF

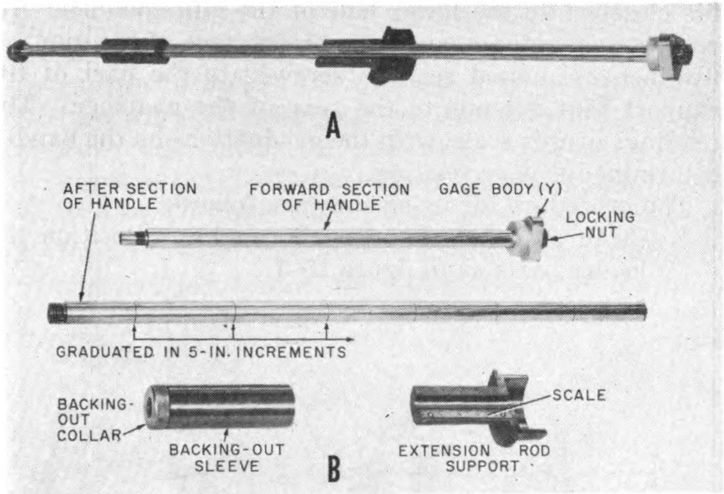


Figure 15–6.—3"/50 bore erosion gage Mk 2 Mod O.
A. Assembled. B. Disassembled.

guns is somewhat different from the 40-mm and 20-mm types discussed above. The Mk 2 Mod 0 gage (illustrated both assembled and disassembled in fig. 15–6) has four principal parts—the GAGE BODY, the SECTIONAL HANDLE, the BACKING-OUT SLEEVE, and the EXTENSION ROD SUPPORT.

The triangular gage body has three raised external gaging surfaces spaced 120° apart on a 3.01-inch diameter circle. The three surfaces correspond somewhat to the **Y** of a star gage, but their diameter is fixed. The handle has two sections. The first section is externally threaded at both ends. The longer threaded end screws into the gage body and locks in position with a nut. One end of the second section of the handle is internally threaded to receive the first section. The other end is externally threaded to receive the backing out collar. The handle is graduated in five-inch increments starting with a 25.0-inch graduation representing a position 25 inches to the rear of the forward gaging edge of the gage body. The final graduation is at 55.0 inches.

The extension rod support, a cast brass half-cylinder, fits closely into the lower half of the gun chamber. Its rim acts as a stop against the breech face of the gun. A five-inch graduated scale is screwed to the part of the support that extends to the rear of the chamber. The readings of this scale, with the graduations on the handle, determine the gage reading.

The procedure for using the gage follows:

1. Clean gun and chamber thoroughly. Position the loader parts as in figure 15–7.

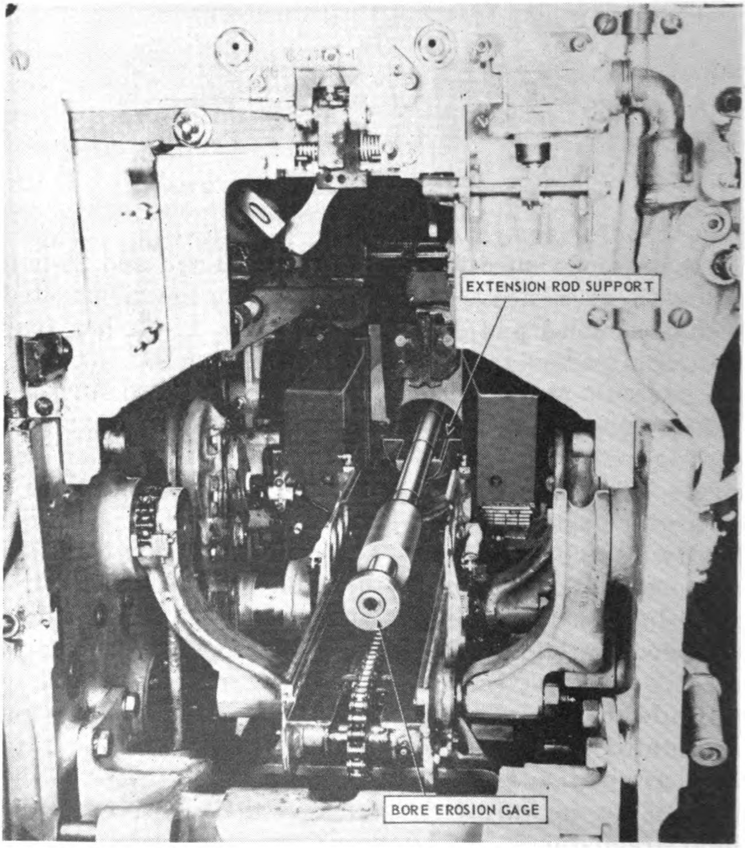


Figure 15–7.—Bore erosion gage Mk 2 Mod O installed in 3"/50 mount.

2. Push the bore erosion gage assembly, gaging surfaces **Y** up into the chamber. They should go in far enough to permit the extension rod support to be inserted and brought up solidly against the breech face, and under the graduated handle. In this position (fig. 15–7) the extension rod support serves as a support and centering device for the gage.
3. Push the assembly forward slowly until the gaging surfaces just contact the gun bore.
4. Check to make certain that the raised gaging surfaces are **Y** up.
5. Using one hand, exert a moderate pressure to seat the gage body firmly. Do not force it forward with a sharp thrust.
6. Read the scale on the extension rod support. To this reading add the reading of the graduated handle.
7. Back the assembly out of the bore and repeat steps 3 through 6. These steps should be repeated until a total of at least three consistent readings is obtained. Readings should be taken to the nearest 0.10-inch graduation.
8. Withdraw the assembly to the position described in step 2. Repeat steps 3 through 7 with the raised gaging surfaces of the gage body **Y** down.
9. Average the consistent readings obtained with **Y** up and **Y** down. This average reading will be the erosion gage reading to be reported.

If the gage assembly sticks when an attempt is made to withdraw it, do as follows:

1. Slide the brass backing-out sleeve (fig. 15–6), which is on the handle forward of the backing out collar, smartly against the collar.
2. If this doesn't work, tap the gage body slightly with a wooden rod inserted in the muzzle end of the gun. The sectional handle provided for sponging guns

may be used if a buffer is placed on the end to avoid damage to the gage or sectional handle.

When not in use, the gage is to be stowed in the box provided. Care must be taken to avoid damage to the gaging surfaces, which are accurately machined and finished.

When you report the gage readings to your leading petty officer or division officer, he uses a section of the range table for the gun to determine the corresponding velocity loss, and then makes out a GUN WEAR REPORT. The information you supply him, to be of maximum usefulness in making out the report form, should give the gun serial number (from the gun itself), the number and type of rounds fired since the last report (from the battery log), and the average gage reading described above, plus any unusual indications (bulging, checking, cracking, peeling, unusual wear and so on) that you have noticed on inspecting the gun bore and chamber.

Gages of this type are available for larger caliber guns, and are used similarly.

Decoppering

A constriction in the bore that will stop a bore gage may, as you already know, be caused by either of two things—excessive deposits of copper, or serious damage to the gun's liner or to the barrel itself.

The second of these two causes is pretty serious, and requires a great deal of expert attention and special equipment available only in naval shipyards, or on ships especially fitted out for the work. Fortunately, this kind of defect is rare. In any event, you as a GM2 are not likely to have much to do with such cases. So let's consider only the problem of copper deposits on the rifling.

There are three principal ways of removing the copper deposits that accumulate on the rifling of naval guns:

1. Mechanical or abrasive methods.
2. Firing decoppering shots.
3. Chemical methods.

MECHANICAL OR ABRASIVE METHODS. These entail use of lapping heads, wire bore brushes, and decoppering heads. You just scrape the copper off the bore.

FIRING DECOPPERING SHOTS. If you put metallic lead (strips, or the like) in the propellant, there is much less copper fouling when a gun is fired. According to present ballistic theory, this decoppering action of lead does not happen because the lead scours or rubs copper deposits away, but because a very thin lead coating discourages copper deposits. When you fire a round whose propelling charge contains lead, the lead is vaporized, and a thin lead deposit settles on the surface of the bore. When you fire the next round, the rotating band of the projectile scrapes away some of the copper already on the bore, but the thin lead coating prevents more copper from being deposited. The decoppering effect continues as long as vaporized lead is deposited whenever the gun is fired. When lead is not deposited, copper from the rotating band can stick to the rifling, and you have renewed copper fouling.

Most propelling charges consequently contain a certain amount of lead to reduce copper fouling. However, the more lead there is in the propellant, the brighter its flash. Most flashless charges now in the service therefore contain a minimum of lead. This means that a certain amount of fouling is likely to occur.

Excessive copper deposits can be removed by firing a few special "decoppering rounds" prepared aboard ship by adding lead foil to the standard rounds. But propelling charges now being manufactured contain lead salts for decoppering effect, so that eventually every shot will be a decoppering shot. If your ammunition is not of late manufacture, however, it will be up to your gunnery officer to decide whether special decoppering shots will be fired.

CHEMICAL METHODS. It is possible to remove copper deposits without seriously affecting the steel gun bore by using a special solution on it. The method is, however, not approved for use aboard ship, since application of the solution, though simple in principle, requires experienced personnel and considerable care.

The method of removing metal fouling with which you will have most to do is the first of these three. In this work you will most likely use either a lapping head or a wire bore brush, though you may have a decoppering tool fitted with blades. Here are points to remember when removing copper fouling with tools like these:

1. It is best to pass the bore gage right after firing to check on whether decoppering is necessary, and to do whatever decoppering is necessary without delay. It is also good practice to check with a bore gage immediately BEFORE firing, too.
2. The main point of decoppering is to remove enough of the metal fouling to permit the bore gage to pass. It can be overdone. If the gage passes, stop decoppering.
3. When lapping or scrapping out metal fouling, do NOT try to work on the entire bore. Work only on the spots where the bore gage will not pass. Decoppering can be slow, tedious work. Don't make it even more so by doing it where it is not necessary. You can locate the constriction by marking the sectional handle or line used for passing the bore gage at the muzzle as the gage encounters the obstruction. Then, when the lapping head or decoppering tool is inserted in the bore, you will know that it is at the correct location when the marked spot is at the muzzle.
4. Emery abrasive can be used in removing fouling, but it's strong stuff and must be used sparingly. You will usually find that your gunnery officer's specific permission will be necessary. You will require special permission also for power tools.
5. The chromium plating on the gun bore is intended to prolong the gun's life. Spare it if you can.
6. Do not attempt to remove "smoke rings" by use of the lapping head or abrasives.

Maintaining Amplidyne Power Drives

In the preceding course in this series and in chapter 4 of this course you learned about the principles of hydraulics and you studied some of the common maintenance operations for electrohydraulic equipment. But except for a brief discussion of principles of operation, we haven't said much about all-electric drives. In this section we'll take up some of the maintenance pointers peculiar to all-electric drives.

At the present time, all the electric power drives used in U. S. naval gun mounts are of the Amplidyne type. The most important types of mounts that use this type of drive (whose principles are explained in chapter 8) include 40-mm Mk 4 quads, 3"/50 RF twins and singles, 5"/54 single mount Mk 39, and the Mk 102 rocket launcher. So you can see that even though the majority of the power-driven gun mounts you're likely to have to service during your career in the Navy are electrohydraulic types, there's a sizable number of Amplidyne-driven types.

For real troubleshooting you can call on the aid of Fire Control Technicians to help deal with Amplidyne drives. But you should be able to handle routine maintenance chores yourself, and that's what we'll go into here.

Amplidyne drives of different mounts have much more of a family resemblance than electrohydraulic drives. Of course, there are circuit differences, but you don't find such radical design differences between a 3"/50 Amplidyne generator and a 5"/54 unit as you would, say, between a Vickers A-end and a Northern Ordnance or Waterbury A-end (to say nothing of a Westinghouse A-end). So the pointers listed below are, so far as Amplidyne systems go, generally applicable.

PERIODIC INSPECTION. As with other equipment, Amplidyne power drive units should be periodically inspected as required by the equipment OP. The best time to do this inspection is just after the gear has been in operation for a prolonged period. Then, when you remove the cover of the case being inspected, you can detect symptoms of overheating much more easily than if you do it cold. Use your hand to feel motor and synchro frames, transformer field laminations, capacitor covers, and the like. Remember that heating is not the same as overheating. Some components, like resistors and tubes and some motors, get hot in normal operation. But after you get acquainted with the insides of the equipment, you'll be able to tell when a component is getting too hot. Look also for other symptoms like charring, a smell of smoke, or melted insulation oozing out of a capacitor case or transformer. Look also for cold tubes. Some amplifiers will continue to function even with a dead tube, so feel all the tubes as part of your inspection. And of course, this is the time to look for loose connections, frayed insulation, and the like.

SEALED HOUSING. To keep them dust proof and watertight, housings of such units as receiver-regulators on 3"/50 mounts are not only sealed but are charged with desiccated (dried) air under pressure to exclude leakage. Failure of the seal will cause the air to leak out and (which is worse) permit moisture-laden air or even water to leak in. These housings must therefore be periodically recharged and resealed. This operation is one which you won't be called upon to do very often, and in that case you'll probably work with an experienced Chief Gunner's Mate or Opticalman. For details on how this operation is performed, see OD 2847.

LUBRICATION. The most important aspect of lubrication around electrical equipment is to keep the lubricant AWAY from where it can do damage. You're already aware of the havoc that petroleum-based lubricants can cause with rubber and other insulators. Keep them AWAY from wiring and wiring conduits or cabling. Oil and grease are also insulators, so they must be kept away from contactors and switch points, except when specifically required by technical manuals, OP's, or lubrication charts. Most important, avoid over-lubrication of fittings and bearings from which lubricant can drip or leak to electrical parts. This is especially true of bearings of rotating electrical machinery.

In indicator-regulators and receiver-regulators which contain servo motors, gearing, and synchros, you lubricate gears, shafts, and ball bearings mostly to prevent corrosion. A thin coating of light mineral oil applied once in six months is sufficient for gears and shafts. Ball bearings require two or three drops of 14–0–20 (ORD) instrument oil or other light corrosion-resisting mineral oil as prescribed by the equipment OP at general overhaul. See OD 3000, *Lubrication of Ordnance Equipment,* for allowable substitutes.

Lubrication of the motor-generators, the train and elevation motors, and similar heavier units is covered in the lubrication charts in the OP for the equipment. Amplidyne generators will whine under heavy loads. This is a normal condition and should not be mistaken for a symptom of dry bearings. Bearings of tachometers and parallax motors should be flushed and repacked with ball bearing grease OS 1350 at overhaul.

COMMUTATORS AND SLIP RINGS of motors and generators should be kept clean and polished. Ordinarily, commutators require only occasional wiping with a piece of canvas or other nonlinting fabric. DO NOT use oil on the commutators. Check the commutators of the parallax motors once a year and true up if necessary.

BRUSHES of rotating equipment should be inspected every six months. They should move freely in the holders and make firm, even contact with the commutator. Replace brushes so worn that they will not last until the next inspection, and brushes which are cracked or chipped. Amplidyne generator brushes may require adjustment after replacement. See the OP on the equipment.

TUBES in amplifiers should be tested every six months, using a radio tube tester. They should be replaced if the test shows a marked departure from rated characteristics. The FT is the man to see about getting tubes tested.

RELAYS AND MAGNETIC CONTACTORS. Inspect contacts on relays and magnetic contactors every six months, and clean if necessary. Use a burnisher or crocus cloth. If crocus cloth is used, clean the contact with alcohol afterward. In telephone-type relays it is often sufficient to draw a piece of tough paper between the contacts while they are pressed together. (Dollar bills are just the thing.) In cleaning, take care NOT to disturb the adjustment of the relays, or to change the spacing between contact points.

SWITCHES. Check switch operation in the control panels and one-man control units every six months. A few drops of light mineral oil, such as Symbol 2110, may be applied to the shaft of a switch if it tends to stick. However, be very careful to keep oil away from switch contacts.

Checking Power Drive Performance

Though they are different in many principles and design features, electrohydraulic and Amplidyne power drives have a good deal in common from the point of view of their behavior. In this section we'll discuss briefly some common trouble symptoms and their possible causes. We won't explain troubleshooting procedures; these are a study in themselves.

ELECTRICAL CONTROL AND POWER CIRCUITS. Although the drive components that drive the mount in elevation and train may be either electrical or hydraulic, depending on whether the power drive is all-electric or electrohydraulic, the CONTROL OR REGULATING parts of the drive are always electrical. And all power drives are themselves electrically driven. All gun mounts with power drives receive their gun order signals through electrical synchro signals in automatic operation. Even in local power, when you operate a handle control unit or crank handwheels, you set up electrical signals to control the drive. Only in hand control on some 5-inch mounts does your handwheel-cranking act directly on the hydraulic power drive elements, through a mechanical connection, to control them. (And, of course, in manual the action is entirely mechanical, without power functioning of any kind.)

In 5"/38 electrohydraulic power drives the electrical control signals are converted to mechanical shaft rotations by small electrical rotating devices called SYNCHROS, which directly operate pilot valves in the hydraulic section of the regulator. The signal is amplified hydraulically until it can drive the mount. In 40-mm YS&L drives (Mk 5, Mk 6, and mods) and others, the synchro signal is converted to an a-c voltage signal which is amplified electrically until it can drive a small motor. The motor then operates a valve to control hydraulic fluid flow in the power drive.

In either case, gun order comes from the director or from plot as SYNCHRO SIGNALS. Periodically, you may be called on to assist FT's in TRANSMISSION CHECKS, which test the synchro system at both ends at once. Known gun order signals are transmitted, and the gun's response is observed. The gun mount and plot or the director are connected by sound-powered phone so that crewmen stationed at either point can compare dial indications and mount response.

If your mount fails to synchronize with transmitted gun order, but follows it with a fixed error—for example, 10°, 20°, or some multiple of 10° off—the trouble is very likely in the synchro system. If the mount follows the signal sluggishly, with a considerable amount of error, the trouble may be in the synchros, though it may also be elsewhere. If the mount fails to follow at all in automatic, even if the power drive is otherwise functioning properly, it may be an indication of electrical failure of the a-c power to the synchro transmission line. In newly installed or overhauled mounts, where there has been repair of the electrical control system, especially involving synchro replacement, the leads may be incorrectly connected. The mount may then train or elevate in the contrary direction to gun order, or may have a fixed large-angle error even though it follows gun order properly.

Here are some other symptoms usually associated with electrical causes. The power motor may fail to start. The first thing to suspect is that the LOCAL-AUTOMATIC switch isn't in the right position (on most mounts the power motor will start only when it's in a certain position) but a defective motor controller or switch contactors may be the cause. The mount may, when gun order remains fixed, HUNT (oscillate) about gun order bearing or elevation, or may DRIFT slowly away from gun order position. Or the mount may even run away, though this is often caused by other than electrical troubles. Electrical troubles can arise from faulty switch functioning; for example, the mount may respond to handwheel or handle control movement when the selector switch is in AUTOMATIC position. Or the local controls may fail to function in LOCAL. The trouble is then likely to be in the selector switch or in relays associated with it. Or an electrical failure can cause troubles in the hydraulic system. Example: In 40-mm mounts with YS&L drive a DITHER MOTOR vibrates the whole hydraulic system whenever the system is energized. Its purpose is to cause hydraulic valves and pistons to respond more promptly. If electrical failure causes it to stop functioning, the mount will still operate in power (local or automatic), but it may fail to follow small changes in gun order, or it may stick or hunt.

In electrical troubles generally, it pays to know your mount. The trouble may be easily solved by replacement of a fuse. It's not your job to adjust synchros, but you can replace a fuse, if you know where to locate the blown fuse and if you have a replacement. But don't be indiscriminate. If the second fuse blows immediately, it will probably be a better idea to get your Gunner's Mate Chief or Electrician's Mate, or the Fire Control Technician on it, than to try to put in a third fuse. And, under NO conditions should you attempt to substitute a slug or a piece of wire for a fuse.

Know your mount. The OP on it always has one or more elementary wiring diagrams which show such things as where the fuses are in a circuit, and the proper type and size. If you know in advance, you can deal with the emergency to the extent that you're authorized to do so.

HYDRAULIC SYSTEMS. There are some characteristic hydraulic system troubles too. We can cover a few here. On 40-mm mounts, you may find that a drive seems to stall when the mount is tilted (as in heavy seas). This is a sure indication that oil level is low. Or you may find that the oil foams. This indicates air in the hydraulic system. Venting will not always cure the trouble, because it's likely that more air can get in. So make sure the oil level isn't low, that the valves aren't spraying oil, and that all fluid lines are tight.

In mounts with hydraulic amplifiers (examples are 5"/38 twins and singles) the guns may fail to respond to gun order in automatic or to handwheel operation in local, but drive in one direction into the stop. This is almost certain to be caused by a hydraulic failure (such as stuck pilot pistons in the hydraulic amplifier) or a mechanical cause (such as loose or frozen linkage between synchros and pilot pistons). With YS&L-type power drives this may indicate a stuck pilot valve, but it's also possible for the trouble to be electrical or mechanical. Or the power motor and A-end may run OK, and the synchros may be functioning properly, and yet the power drive may fail to budge the mount either in local or automatic. This is most likely to be a hydraulic malfunction. Maybe the transfer valve, which is supposed to be open only in manual, isn't closing because it's defective or because of defective linkage to the selector lever. Or the A-end tilt plate or yoke may be stuck. Oil may be low. Or the replenishing pump, which feeds oil under pressure into the active system lines, may be defective.

In both electrical and hydraulic troubles we've touched on only a few possibilities. But, as you may very likely have discovered already, one of the main difficulties in mount power drive troubleshooting is that so many symptoms can be caused by EITHER electrical or hydraulic troubles. Suppose, for example, that gun movement is sluggish. This might be caused by anything from air in the hydraulic system to an open-circuited synchro. But here are two principles you can use for helping to run down the cause of any specific symptom:

1. What other symptoms accompany it? For example, if the hydraulic oil shows signs of foaming, it's more likely that the cause of sluggishness is trapped air in the system than that the synchros are to blame. Tackle that possibility before you holler for help from your chief or from the FT to test the synchros. Look for other clues too—abnormal noises and other details of behavior. And check all the other obvious things too—like blown fuses, gun trained or elevated into limit stop, incorrect control settings, and the like. Above all, know your mount.
2. Shift from one type of control to another. For example, if you pursue the cause of sluggish operation and switch from automatic to local, it's easy to tell whether the cause is in the synchro system or in the hydraulic system. Obviously, if sluggishness persists, the synchro circuits are not at fault. If sluggish performance persists even when in manual, then obviously neither the power drive nor the control circuit can be blamed. Look for such causes as low lubricant level, or the wrong lubricant for the climate. Look also for more subtle causes; the subtle ones are the ones that cause the headaches. Here, too, it pays to know your mount, and to study the OP BEFORE things go wrong.

Checking Hoist Functioning

All hoists used in naval rocket mounts, gun mounts, and turrets are electrohydraulic and most are semiautomatic. (You start them, and they stop themselves.) The others are fully automatic. All of them have interlocks, to a greater or lesser degree, to prevent mechanically errors that may be made by their operators, and to prevent conflicting actions.

Hoists are fairly complex mechanisms, and we don't take them up in detail in this course. But you should get to know the hoists of the mount you're responsible for, and what to do for them when they develop troubles. Being hydraulic, they share many of the same troubles that you find in electrohydraulic power drives. Their control systems are usually combinations of mechanical and hydraulic devices, with many of them operated by electrical units, particularly solenoids.

When you check a hoist for proper operation (and this should be done with the guidance of check-off list, OP, or both), be especially certain to check ALL safety devices. Make sure, for example, that a 5"/38 projectile hoist won't start a new hoisting cycle with a projectile in the top stage. The doors at the lower end of every hoist must be properly connected to the interlock to prevent the hoist from starting during loading. Before a hoist drive is energized, it's a good idea to see that there isn't any obstruction in the path of the moving parts. In chain-operated hoists like those used in 5"/38 mounts, make sure so far as you can that the chain links are in good condition—in both the hoisting and fuze-setting chains.

Chain-type fuze setters are the standard type for all 5-inch projectile hoists except for the Mk 42 mount, which has a different type entirely. The fuze setter drive is an electric motor controlled through synchros. It positions the fuze setter chain, which in turn through a sprocket and worm rotates a device in the projectile flight which engages the fuze ring. The usual method for checking fuze setter operation is to let a known setting signal be transmitted from plot. Then a dummy projectile fitted with a dummy time fuze is sent up in the hoist. The fuze MUST be set at zero when it is loaded into the hoist. When it's taken out at the top of the hoist, its setting should correspond with that transmitted. Fuze setters are relatively simple, and aside from the synchros and drive motor, are entirely mechanical and should offer no troubleshooting problems.

NEVER use a live round for checking fuze-setter operation.

Rocket Mounts

The Mk 102 and Mk 108 rocket mounts that we've discussed elsewhere in this book present maintenance problems much like those of gun mounts, and much in the preceding sections of this chapter really applies to them too.

Since they have no recoil and counterrecoil mechanisms, rocket mounts haven't the maintenance work associated with such systems, but they do have some special maintenance problems of their own. For one thing, nobody can stay close to the tubes of either of these rocket mounts while it's firing. This means you have less warning of malfunctions that you do with a gun, and when the tubes and carriage are hot you have to be careful of how you work around them. Also, rockets are fired by open contacts of a type that you don't find around gun mounts. The contacts take looking after; a misfire in a rocket is no more pleasant than with a gun. Here, again, know your equipment, and closely follow the OP on maintenance.

SUPERVISION OF ROUTINE MAINTENANCE WORK

As a GM3 you've probably had some supervisory responsibilities now and then, but on the whole you've been more the supervised than the supervisor. With the extra stripe on your arm you'll be a bit higher in the pyramid, and you'll have more of those responsibilities.

In this section we won't try to duplicate the general training in supervision that you get in your training as a petty officer. We're primarily concerned here with your supervisory duties as a GM2, particularly as they relate to routine maintenance.

Routine maintenance isn't exciting, it doesn't tax the brain very much, it can be dirty, and though it may require a respectable amount of effort, it doesn't show any direct, positive, observable results. You remember the old fable about the nail that fell out of the horseshoe, causing the loss of the shoe and eventually of an entire kingdom. What was needed to keep the nail in the shoe? Routine maintenance! It's an old story, and it's been used in the Navy to illustrate the importance of preventive maintenance since approximately the year 1.

But here's a different angle to the story. Suppose the groom or blacksmith who was responsible for that undone bit of maintenance had done his job properly instead of flubbing it. Presumably the horse and rider would have accomplished their mission, the battle would have been won, and the kingdom saved. And then, would the groom or blacksmith have gotten a gold medal?

The answer is, of course, no. You don't get a gold medal just for doing your job, especially if it's routine maintenance. But it's important just the same. Its importance cannot be measured by its reward. Yet the job has got to be done. You will be doing less of it, but you will be responsible for more of it.

The primary considerations that you're concerned with in supervising strikers and lower rated men in routine maintenance are:

1. Every day's (or week's, or month's, or quarter's . . ., and so on) work must be done when it's supposed to be done.
2. It must be done thoroughly.
3. It must be done safely.

You remember the check-off list. The supervisor needs it as well as the man actually doing the job. You use it both to get the work done on time, and to see that it's done thoroughly. The list is only a piece of paper, but it's mighty important and very useful. Make sure it's followed to the letter. If it's out of date, or inaccurate, see your chief about it. But if he's on the ball, you can depend on that list. And make sure that your men understand how important it is, and how to use it.

Safe and thorough working methods are a matter of training and habit. If you get your men into the right habits, they'll follow them. Remember that you set an example, especially when you're demonstrating how to do a job. And demonstrate you must. Don't take it for granted that a new man knows how to do a given job, until you've seen him perform it satisfactorily. This means you'll have to show him. In your position, you've got to know how to do these jobs as you expect your men to do them.

SUMMARY

In the next chapter we take up boresighting and tramming. This is an exceedingly important part of your maintenance work. It isn't done frequently, but the effectiveness of your ship as a fighting unit is as dependent on these adjustments as it is on any other single factor.

QUIZ

In the multiple-choice questions 1 through 8 and 10 through 14, select the ONE best answer.

1. Which of the following kinds of work is intended to modify ordnance gear so that it will be improved over its original design?
   a. Corrective maintenance
   b. Upkeep
   c. Troubleshooting
   d. Alteration
2. Suppose a new ordnance equipment is to be installed on your ship. In which of the following types of drawings about the equipment will you be MOST likely to find information indicating the proper clearances to allow for operation and servicing of the equipment?
   a. Outline drawing
   b. Assembly drawing
   c. Elementary wiring drawing
   d. Detail drawing

3. Which of the following kinds of drawing is the most likely to be useful in hooking up the equipment mentioned in the preceding question to the ship's electrical system?
   a. Installation drawing
   b. Internal wiring drawing
   c. External wiring drawing
   d. General arrangement drawing
4. Which of the following types of wiring drawing is LEAST likely to identify connection points like terminal boards, plugs, jacks, and the like?
   a. Schematic
   b. Elementary
   c. External
   d. Internal
5. What is the main difference between a BuOrd line sketch and a BuOrd drawing?
   a. A sketch is not as accurately made as a drawing
   b. A sketch is a pictorial representation of the subject, while a drawing is not pictorial, but an exact line representation using standard drafting techniques, showing dimensions, and so on
   c. A sketch relates to experimental or preliminary ordnance designs, while a drawing relates to standard service gear
   d. A sketch uses nonstandard symbols and drafting techniques, while a drawing always is made exactly to standard practices and with standard symbols
6. A Master List of Drawings is prepared for
   a. each assembly of an ordnance equipment
   b. all the drawings relating to the ordnance equipments on a given type of ship
   c. all the drawings available in the Bureau of Ordnance
   d. each major ordnance equipment
7. Which of the following is the BEST source of information for making up work requests?
   a. Battery logs
   b. Check-off lists
   c. Machinery history
   d. CSMP
8. During the time that a ship is undergoing overhaul in a naval shipyard, the ship's main "contact man" with the yard organizations is the
   a. ship superintendent
   b. engineering officer
   c. gunnery officer
   d. executive officer

9. In figure 15-8, what is the vernier reading:
   a. In the upper diagram?
   b. In the lower diagram?

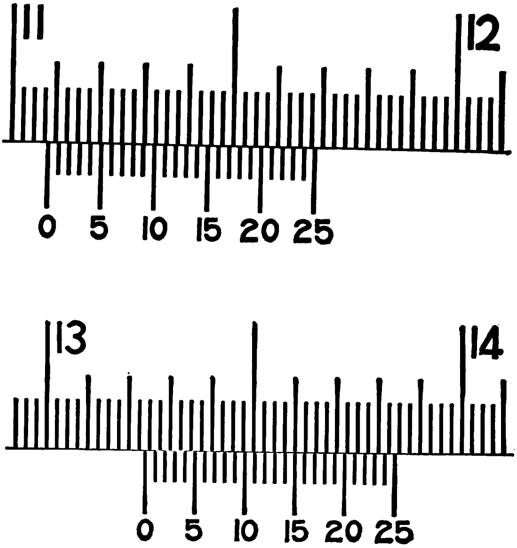


Figure 15–8.

10. The principles on which the bore erosion gage functions is that it measures:
    a. Advance of the forcing cone
    b. Wear of the lands and grooves of the rifling
    c. Wear of the rotating band
    d. Ballistic effect of worn gun bores
11. After you have erosion-gaged a 3"/50 gun, your report to the gunnery officer need not state the
    a. number and type of rounds fired since the last report
    b. gun serial number
    c. loss of initial velocity indicated
    d. averaged gage reading
12. The purpose of decoppering is to eliminate from the gun bore:
    a. Powder fouling
    b. Metal fouling
    c. Wear of the lands and grooves
    d. Smoke rings

13. Which of the following malfunctions is definitely indicated by the whining of an Amplidyne generator operating under heavy load?
    a. Dry or underlubricated bearings
    b. Overspeeding
    c. Motor overload
    d. None

14. When a gun mount is said to HUNT, it
    a. drifts off gun order position
    b. stays off gun order position by a constant angle
    c. oscillates about gun order position
    d. follows change in gun order sluggishly

CHAPTER 16

BORESIGHTING AND TRAMMING

BATTERY ALIGNMENT

In fire control, as you already know, the bore of the gun is actually the first part of the projectile's trajectory. Other things being equal, whether or not the projectile hits its target depends on how the gun is aimed.

Aiming, in turn, depends on the sights and on the rest of the fire-control equipment. Yet saying that does not tell the whole story. Today's Navy uses the best guns and the best sighting and fire-control equipment there is. But guns plus sighting and fire-control equipment are no automatic guaranty of accurate fire—unless they are accurately lined up to work together.

The process of lining up the guns (or the rocket launchers and projectors) of a battery with the sighting and fire control equipment that directs its fire is called BATTERY ALIGNMENT. It's a big and important job that involves the cooperation of Gunner's Mates and Fire Control Technicians.

The complete gun battery alignment job is pretty complex, and involves not only the gun mounts and turrets but the director, computer, fire-control radar, and data transmission. The best general reference on battery alignment is OP 762 (now under revision). But in this course we're mainly concerned with two phases of battery alignment—boresighting and tramming. We'll take up boresighting first.

WHY BORESIGHT?

Boresighting is necessary because of an assumption you make whenever you use a gun sight telescope to aim at a target. The assumption is (you should remember this from the chapters on fire control) that sight angle (or deflection angle) is measured from the gun sight's line of sight to the AXIS OF THE BORE. Boresighting is simply the process of making that assumption a true one: It makes the sight angle and deflection dials mean what they say. We can best define it as the procedure used for adjusting gun sights so that at zero deflection and sight angle the lines of sight through the gun sights will either be parallel to the axis of the bore, or will intersect the bore axis at a specified range.

The gun sight lines of sight and the axis of the bore of a gun can intersect at only one point. Thus a gun can be boresighted with perfect accuracy at only one range. The sights will be in error at other ranges. To minimize this error, weapons of relatively short range, like machine guns, are boresighted at the range for which the weapon is best adapted—the MEAN BATTLE RANGE. You will find, therefore, that 20-mm guns, for example, are boresighted so that at zero deflection and sight angle, the lines of sight through the sights and the axis of the bore converge at about 1,000 yards.

Guns 5-inch and larger have mean battle ranges of several miles. Their sight telescopes, however, are located only a few inches or at most a couple of feet from the gun barrel. The result is that at such ranges the lines of sight through the sights and the axis of the bore converge very little—so little that they can be considered parallel, for all practical purposes. Such guns are therefore often boresighted either "at infinity" (which means that the target is considered to be an immeasurable distance away) or at very distant targets—distant enough so that their exact range is unimportant. A star or other heavenly body is at "infinite" distance for boresighting; a ship or landmark near or on the horizon is also distant enough to be a suitable boresighting target.

FUNDAMENTALS OF BORESIGHTING

Basic Method for Boresighting on Distant Target

In figure 16–1 you can see how the basic method of distant-target boresighting works. Here, the target at which the lines of sight and the axis of the bore intersect is a distant lighthouse. The target could as well be some other distant but clearly defined landmark, or a heavenly body like the sun or a star. Or it could be set up at the prescribed "mean battle range." The boresighting procedure is the same.

Your gunnery officer or one of his ranking assistants will decide on the exact range and target to be used in boresighting. Boresighting procedure varies in detail from one gun to the next, but its fundamental steps are:

1. Establish the axis of the bore.
2. Check for and eliminate lost motion and looseness in the sight mechanism.
3. Sight the axis of the bore so that it is aimed at a specific target set at the prescribed distance (either "infinity" or the specified battle range).
4. Set sight angle and deflection at zero.
5. Sight through the telescopes at the target, and adjust the telescopes WITHOUT DISTURBING THE DIAL SETTINGS.
6. Check the work.

That, as far as fundamentals are concerned, is all there is to the basic method of boresighting. In practice, though the fundamentals are the same all the time, there are some complicating details.

The most important of these is concerned with the first step—establishing the axis of the bore. You don't just open the breech and squint through. Since this is a precision operation, you must use a precision optical instrument—the BORESIGHT. We'll go into further detail on boresight equipment later in this chapter. First let's

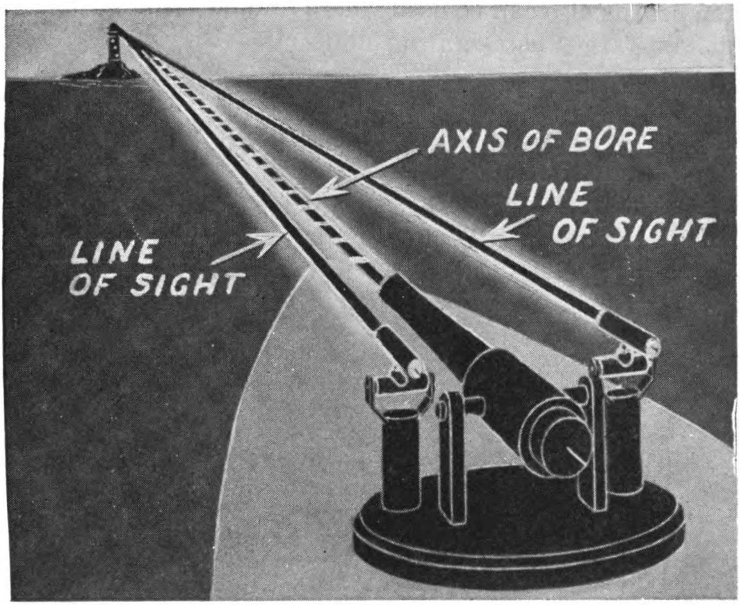


Figure 16–1.—Boresighting on a distant target.

briefly consider a method of boresighting somewhat different from the basic distant-target method most often used.

Basic Methods for Boresighting with Batten Board

Boresighting can be done by use of a BATTEN BOARD. A batten board is a flat (usually wood) panel on which target markings are tacked or painted. The batten can be set up on the ship's deck, or it can be attached to the gun muzzle. Batten boards are used generally when the ship is in drydock or under construction. Their main advantage over distant-target boresighting is that they can be used to check on the accuracy of sight mechanisms at more than a single sight angle or deflection setting. Boresighting on a distant target checks sight accuracy only at zero sight angle (2,000 on most sight angle dials) and zero deflection angle (500 on most deflection dials). Batten boards also can be used where limited visibility makes distant-target boresighting impracticable.

Batten board boresighting can be done in two ways. Each has its own special uses. One method is to set up the batten board on its own support, with target markings painted on it or attached to it. In figure 16–2 we see such a set-up for a 5"/38 open mount. The exact dimensions for the target pattern are shown at the left.

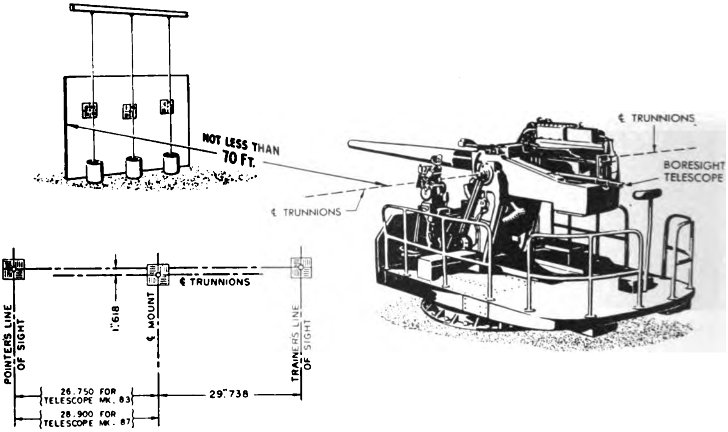


Figure 16–2.—Boresighting with separate batten board.

The targets are spaced to correspond with the spacing of the telescope lines of sight and the gun bore axis, with sights at zero sight angle and deflection. Three plumb bobs are suspended in front of the targets. (The bobs are immersed in water in the buckets; this quickly damps out any tendency to vibrate.) The lines are long enough to accommodate a gun elevation of at least 30°. The lines and batten are set up about 70 feet from the mount. Then the mount's roller path must be made horizontal, and finally the mount is trained and elevated and sight cross-hair movement is observed to see how well it coincides with the lines on the batten. The procedure (here given only in brief summary) is elaborate and painstaking, and because of the requirement that the roller path be horizontal, you're not likely to have to do it aboard ship. This method's main purpose is to establish the accuracy of gun movement in train and elevation.

Another variety of batten board is used for verifying the accuracy of sight movement in elevation and train. This batten is a frame carefully aligned and secured to the chase of the gun. Figure 16–3 shows the set-up for a Mk 39 5-inch mount. The principle of this boresighting procedure is to plot targets and line-of-sight traces vertically and horizontally on the board, then to check the accuracy with which the sights follow the traces by cranking them vertically and horizontally and watching the crosshairs. The batten can also be used to check for lost motion. However, unlike the separate batten board method, the chase-mounted batten boresighting procedure can be performed aboard ship.

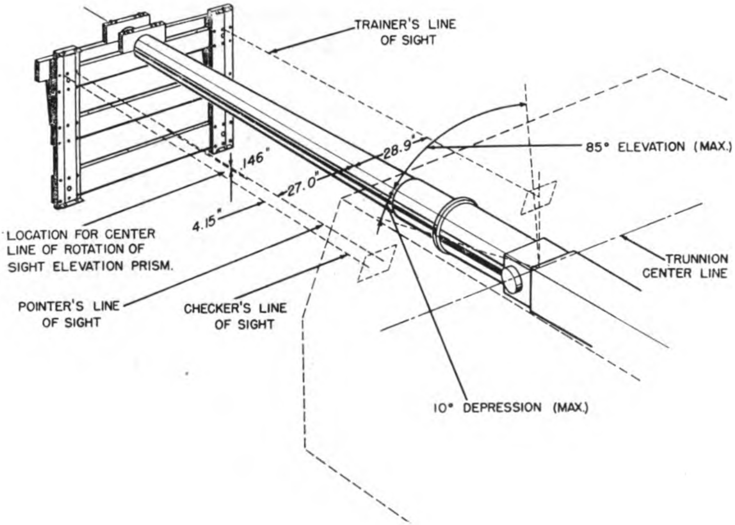


Figure 16–3.—Boresighting with chase-mounted batten board.

Both batten board boresighting methods are relatively rare, and we won't go into the detailed procedures here.

(See the OP on the gun mount if you are called upon to boresight with a chase-mounted batten.) But you are expected to know how to boresight on a distant target, so the remainder of this chapter is worth your close study.

Boresights

We've considered briefly and in a general way the principles of boresighting. Now let's look at the equipment that's used in boresighting. The main item is the BORESIGHT.

The boresight is an optical instrument for establishing the axis of the bore of a gun and for sighting along it. There are two main types:

BREECH-BAR BORESIGHTS. In this type, a BORESIGHT TELESCOPE is mounted in the center of the gun breech by use of an adapter, and is lined up with the gun axis by sighting on a device mounted in the muzzle. Three kinds of boresight telescope for breech-bar boresights are now in use in the Navy—the Mk 8 Mod 6, and the Mk 75 Mods 0 and 1. Any of the three can be used in any breech-bar boresight. The other components of each breech-bar boresight can, however, be used only with the weapon for which they are intended. Only the telescopes are freely interchangeable. Figure 16–4 shows a breech-bar boresight installed in the breech of an 8-inch bag-type gun.

BORESIGHTS WITH SELF-CONTAINED OPTICS. This class includes a variety of boresights. The feature common to most of them is that, when installed, they convert the entire gun barrel into a boresight. Some have no lenses —they consist merely of crosshairs in an adapter at the muzzle and a small peephole (for instance, a little hole drilled in the center of the base of a cartridge case) at the breech; the line of sight, as it runs through the peephole and the intersection of the crosshairs, coincides with the bore axis. Other boresights have optical lenses in adapters that mount at breech and muzzle; thus the gun barrel becomes, in effect, a giant telescope.

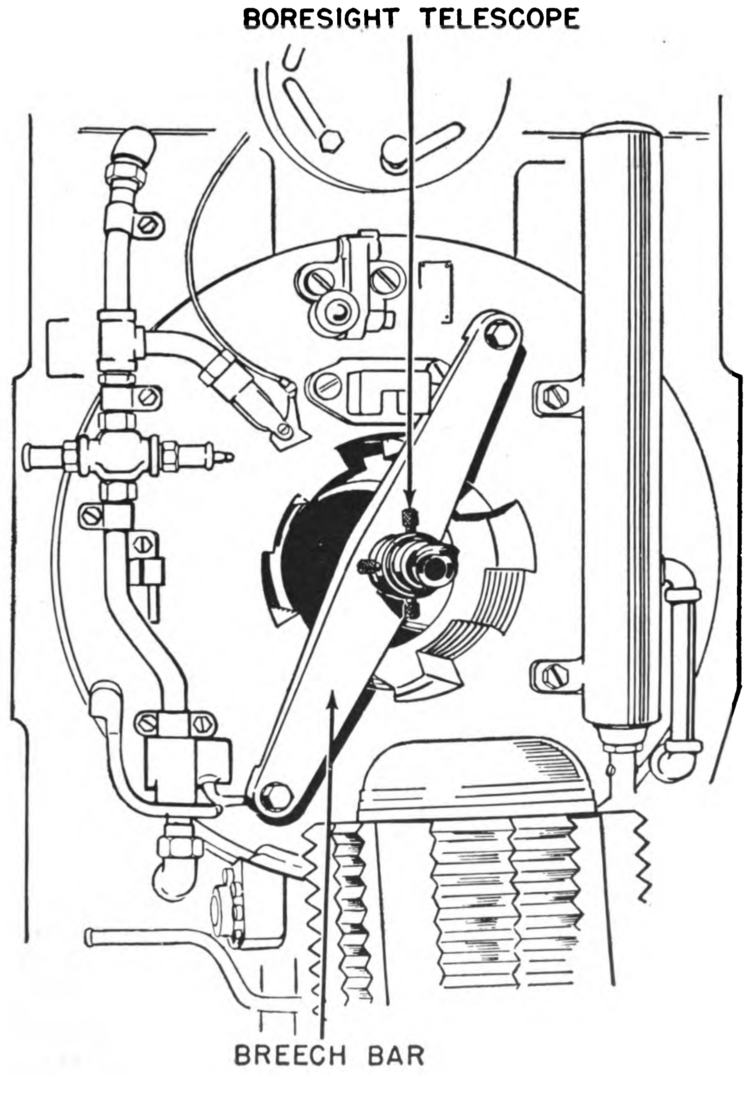


Figure 16—4.—Breech-bar boresight installed in bag-type gun (8-inch).

This type of boresight in a 40-mm gun is illustrated in figure 16–12B. Most of the barrel is omitted to show how the breech and muzzle units of the instrument are installed.

One other variety of this type of boresight is the MANDREL boresight (fig. 16–10). This consists of a steel tube or mandrel that fits into the muzzle of the gun and can be centered and secured therein by an expansion fitting. A bracket holds the telescope rigidly parallel to the mandrel. In this type of boresight the line of sight established is parallel to the real axis of the bore, but outside it; however, the small error is not important. The advantage of the mandrel boresight, which is used with 20-mm guns, is that it isn't necessary to fuss with optical elements that must be fitted into a small gun bore.

Boresighting with Different Types of Sights

One of the details that varies on different types of mounts is the kind of gun sight used. Sights may be either of the YOKE or SLIDE type (like the 3"/50), or of the CARRIAGE-MOUNTED type (like the 5"/38). No matter which type they are, sights should be adjusted during boresighting with sight-angle and deflection dials at zero. But the exact method of adjustment varies with the type of sight. Yoke- or slide-type sights are adjusted by moving the sights in their mountings; carriage-mounted sights are adjusted by loosening and resetting the couplings in the connecting shafts between the dials and the sight optical elements.

Other Sight Checks

The most elaborately boresighted sights will be of doubtful value if the dials start moving ahead of the optical elements when you crank the handwheel, or if the shock of fire knocks the setting off. Therefore, no matter what kind of sight mechanism is involved, eliminating lost motion and looseness in it is an essential part of the boresighting procedure. In this course, because of the various types of sight mechanisms in service, no specific instructions can be given on just where and how to tighten up the mechanism of the mount for which you are responsible, and how to eliminate lost motion. That information is in the OP. The next section will describe simple tests for determining lost motion and looseness. You can use these tests on any mount.

The exact details of the boresighting procedure depend, of course, on just which type of boresight is used with the gun. In this chapter we take up in detail the boresight instruments and procedure for the 5"/38, and discuss briefly boresights for other weapons.

HOW TO BORESIGHT THE 5"/38

Now let's see how the 5"/38 single mount is boresighted. Remember that the actual boresighting process is not very complicated in principle. But, like any other process connected with gun sights it demands accuracy above all. For this reason boresighting must be preceded by careful preparation, and followed by careful checking.

There are two different boresights at the present time that can be used with the 5"/38—Mk 32 Mod 1, and Mk 38. Mk 32 Mod 1 is of the breech-bar type; Mk 38 is of the self-contained optics type. We'll take up here the procedure for breech-bar boresight Mk 32 Mod 1, using boresight telescope Mk 8 Mod 6. Except for details of installing the adapter, this procedure applies to all breech-bar boresights.

The boresight telescope is used to establish the axis of the bore of the gun and to sight along it. Often it's called a "borescope", but since the term "borescope" is also applied to an entirely unrelated device used at arsenals for inspecting gun bores, the boresight telescope will here be referred to only as "boresight telescope."

Mounting the Boresight Telescope

The boresight telescope mounts right in the center of the gun breech. The first thing to do before installing it is to open the breech and secure the breech mechanism so that the breech cannot accidentally close and mash up the telescope. This must be done when ANY gun is boresighted. On the 5"/38, also secure the rammer spade so that it cannot accidentally drop on the boresight telescope. One way to do this is to raise the rammer spade to the upper track of the cam plate and push it forward about six inches.

Next, mount the boresight telescope in the center of the breech, using an ADAPTER. For some guns the adapter is a bar that can be secured by screws across the open breech, as in figure 16–4 (whence the name "breech-bar"). The bar has a threaded hole into which the telescope screws. But on the 5"/38 the adapter is a U-shaped TELESCOPE HOLDER BRACKET secured to the housing by a metal pin or DOWEL, and a cylindrical TELESCOPE HOLDER (fig. 16–5). The dowel fits into a hole in the housing. The telescope holder fits snugly into the bracket. Its front end has a conical surface that fits into the breech; the after end has a threaded bushing into which the telescope screws. All these components are accurately machined so that, when mounted, the telescope is securely posi-

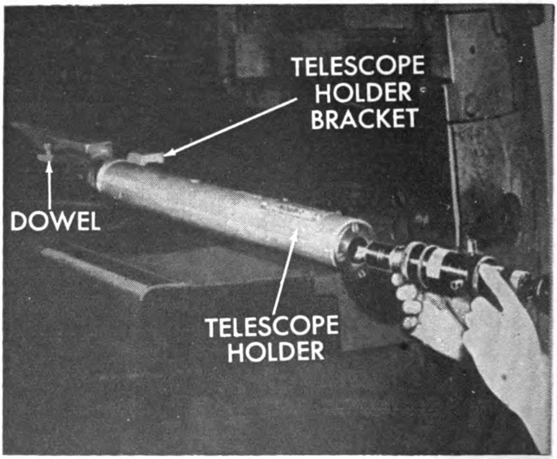


Figure 16–5.—Installing boresight telescope in 5"/38 breech.

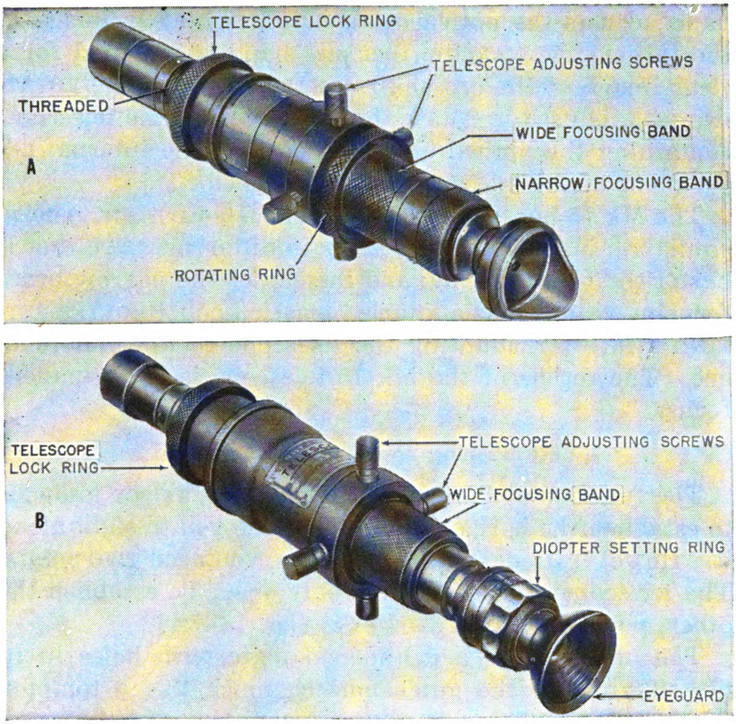


Figure 16–6.—Telescopes for breech-bar boresights. A. Mk 8 Mod 6. B. Mk 75 Mod 0.

tioned on the bore centerline, with its eyepiece just beyond the rear of the slide. Scribe marks on the holder and gun help you align it properly.

The Mk 6 Mod 8 boresight telescope (fig. 16–6A) has two tubes, one inside the other. The inner tube contains the optical elements. Its position within the outer tube can be adjusted by four ADJUSTING SCREWS. When the threaded part of the telescope is screwed into the telescope holder, and the LOCK RING is tightened to secure it, these screws must be, respectively, horizontal and vertical.

Besides these adjusting screws, the telescope has two focusing bands and a rotating ring. The WIDE focusing band adjusts the optical system to get a clear image of the target; the NARROW focusing band is adjusted for a clear image of the crosshairs in the reticle. The ROTATING RING is used to rotate the inner tube of the telescope, containing the optical elements, so that the internal adjustment of the telescope can be checked.

The Mk 75 boresight telescope (fig. 16–6B) is in general similar to Mk 8 Mod 6. The main differences are that it hasn't the rotating ring, and instead of the narrow brass focusing band it has a knurled plastic knob (DIOPTER SETTING RING) for adapting the telescope to the individual eye. The reticle of the Mk 75 telescope is in permanent focus.

Establishing the Axis of the Bore

The function of the boresight telescope, as you know, is to establish the bore axis and to enable you to sight along it. However, to define the bore axis, you need TWO points. The telescope at the breech is only one. To establish the other, you insert a MUZZLE DISC (fig. 16–7A).

The muzzle disc, a cylindrical plate with holes in it, fits snugly into the gun's muzzle, much like a tompion (fig. 16–7B). There is a small PEEP HOLE in the exact center of the disc, and four larger holes at 90° intervals around it. There are also two larger holes in the cylindrical part. The cylindrical part is machined so as to taper slightly, and is encircled with closely spaced lines parallel to the disc surface. These features make it easier for you to insert the disc squarely.

When inserting the muzzle disc:

1. The word TOP on the disc should be at the top.
2. The four scribe marks on the disc should match up with those on the muzzle of the gun.
3. The lines on the exterior of the cylindrical part should be parallel to the muzzle.
4. The safety lanyard provided should be run through the large holes and secured to the barrel, so that if the disc falls out no damage will be done.

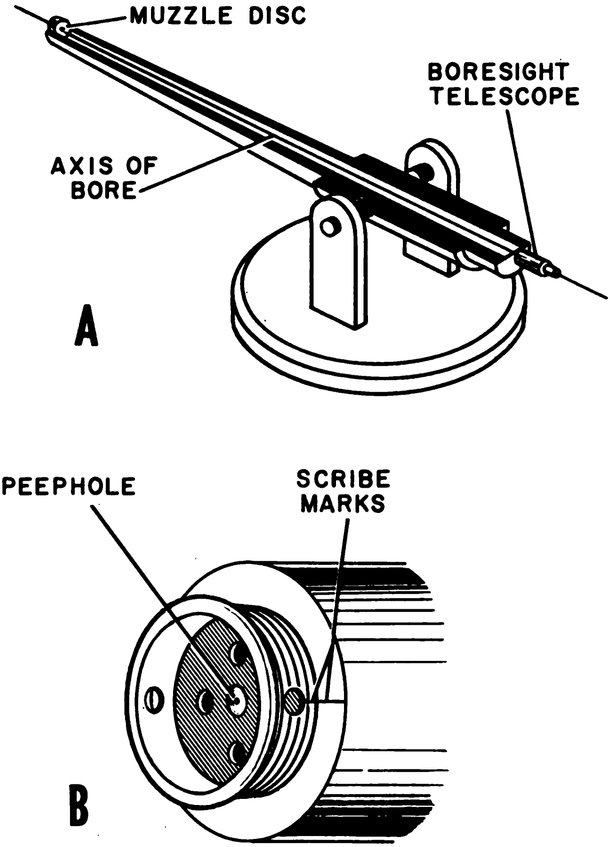


Figure 16–7.—The muzzle disc. A. Function in establishing axis of bore. B. How it is mounted.

5. Do NOT drive the disc home with excessive force. It's not intended as a permanent fixture. Tap it lightly until it is firmly in, but not too tight.

Now you're ready to line up the line-of-sight of the telescope with the axis of the bore. Look through the telescope. If you see something like the picture in figure 16–8A, there are several things wrong—

1. The muzzle disc is out of focus.

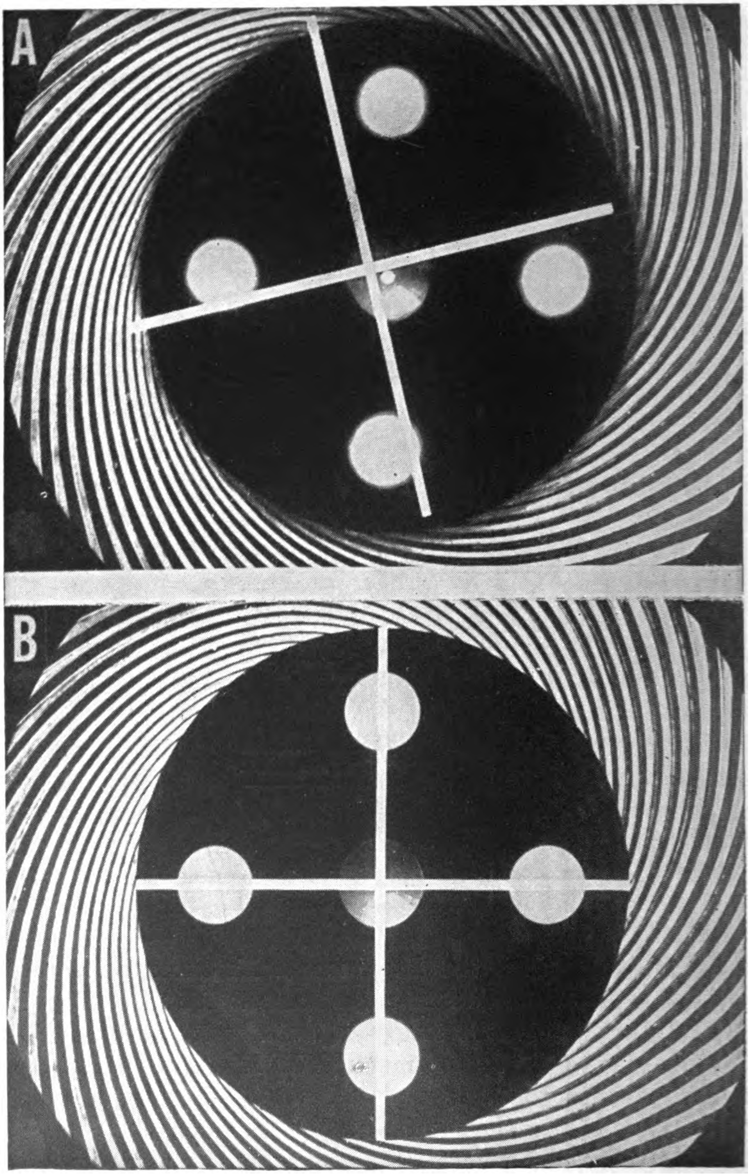


Figure 16–8.—What you see through the boresight telescope (breech-bar type). A. Before adjustment. B. After adjustment.

2. The crosshairs in the telescope reticle are tilted from correct horizontal-and-vertical position.
3. The crosshairs don't intersect on the peephole, as they should.

Take care of these points just as they have been listed:

1. To focus on the muzzle disc, adjust the WIDE FOCUSING BAND on the telescope.
2. Next, turn the rotating ring to move the crosshairs so that they are vertical and horizontal. (Later model telescopes, like the Mk 75, cannot be rotated.) You can judge when they're correctly adjusted by using the large holes in the muzzle disc as guides. After rotation, the crosshairs may not intersect on the peephole; this is adjusted in step 3 below.
3. Last, shift the crosshairs by using the four ADJUSTING SCREWS. These screws shift the entire inner tube assembly of the telescope, so that you can line it up with the axis of the bore. It's lined up when the intersection of the crosshairs is right over the peephole. Use care, not force. Work the screws in opposite pairs (top-and-bottom, right-and-left) until the crosshairs intersect exactly on the peephole. Loosen one of a pair before tightening the other.

You should now see the "after" picture (fig. 16–8B) when you look into the telescope.

Next, check for optical errors. While looking through the eyepiece, move your head around slightly and see if the crosshairs seem to shift against the background of the muzzle disc. If they do, your telescope has CROSSHAIR PARALLAX. You can remove it by adjusting the wide focusing band carefully. When parallax has been removed, the crosshairs may be slightly displaced from the peephole, but they will not appear to move when you move your head. After correcting for parallax you will, of course, have to bring the crosshairs back on the peephole if they have moved off.

If there is any indication of other optical errors, of poor telescope adjustment, or of such defects as loose or misaligned lenses, don't use the instrument until it has been corrected, inspected, and passed by a qualified Opticalman.

The last check you make in establishing the bore axis is to verify that the muzzle disc peephole is in alignment. To do this, remove the disc, rotate it 180°, and replace it with the label TOP at the bottom. The peephole should still be in alignment. If it isn't, get another muzzle disc.

Checking for Lost Motion

When you've made the final check, remove the muzzle disc. With the boresight telescope lined up on the bore axis, you are ready to check for lost motion in the sight mechanism. There are two such checks to make:

FIRST: All sights, whether of carriage-mounted or yoke (slide) type, can have lost motion in their sight-setting mechanisms. This can be checked without using the boresight.

SECOND: Carriage-mounted sights (but not yoke sights) can, in addition, have lost motion in the connecting shafts and gearing that transmit from the gun its motion in elevation. This check requires the use of the boresight telescope.

Let's first take up the check for lost motion in the sight-setting mechanism. One man can make this check, but it's better to have three—one at each sight telescope and one at the sight setter's station.

1. Run the sights all the way up and down, and all the way right and left, to be sure that they are in good working order, and do not bind.
2. Set the pointer's sight telescope crosshairs on some target point on the ship. Any firmly secured, clearly marked object will do. Note the sight angle dial reading.
3. Run the sights up to maximum range or greatest possible sight angle on the range dial or sight-angle

indicator. Then, looking through the telescope, sight again at the point selected for step 2, USING ONLY THE SIGHT-ANGLE HANDWHEEL. Do not move the mount in either train or elevation after step 2 in this check. Turn the sight-angle handwheel in ONE DIRECTION ONLY. If you go past the target and have to crank back, repeat the operation.

4. When the telescope is back exactly on the target point, read off the sight-angle dial indication. If it is precisely the same as the step 2 reading, or is no more than one minute off, lost motion in the sight-setting mechanism, as far as sight angle is concerned, is not excessive. If it's over one minute off, you'll have to eliminate lost motion. The exact method you'll use for shimming gears and taking up the slack in order to do this is covered in the OP on the mount.
5. Go through a similar process to determine lost motion in deflection. The difference is only that you use the trainer's telescope and deflection handwheel.

That's how to take care of lost motion in the sight-setting mechanism, and the procedure is similar on all naval gun sights. For the additional check, mentioned a few paragraphs earlier, for detecting and measuring lost motion in the elevation transmission mechanism between the gun and CARRIAGE-MOUNTED sights, you use your boresight telescope. Three men are enough for this detail—one at the boresight telescope, one at the sight setter's station, and one at the pointer's station. This check should follow the check on the sight-setting mechanism. Here's how it's done:

1. Position the gun in elevation and train until the boresight telescope's crosshairs are on a convenient target point on the ship.
2. Bring the pointer's sight telescope onto the same target by using the sight-angle and deflection handwheels. Note the reading on the sight-angle dial.

3. Elevate the gun a considerable distance above the target—30° or more. Then depress it until the boresight telescope's crosshairs are again on target. Approach in the downward direction only. If you go past the target and have to reverse direction, elevate the gun again and repeat.
4. With the boresight telescope crosshairs on target, look through the pointer's telescope. If there is lost motion in the mechanism, the crosshairs will NOT be on target. Bring them on with the sight-angle handwheel, and read the sight-angle dial again. The difference between this reading and that in step 2 is the error of the sight in this direction.
5. Repeat steps 2 through 4, this time DEPRESSING the gun and returning the boresight crosshairs by moving the gun UPWARD only. Note the error in this direction also.
6. Add the two errors and divide by 2. This will give you the average or MEAN ERROR caused by lost motion. From this error, subtract the error found in checking the sight-setting mechanism. The result should be under one minute. If it is not, the lost motion must be eliminated as much as possible. See the OP about that.

To check for looseness in the sight mechanism, shake it. If there is any noticeable change in scale setting or alignment of the line of sight on the target, you have a tightening-up job to do.

The Boresighting Operation

You have lined up the boresight telescope and have eliminated excessive lost motion from the sight mechanisms. You are now ready to boresight.

Boresighting on the 5"/38 and other mounts with carriage-type sights usually requires a crew of four—pointer, trainer, a man at the boresight, and a man to reset adjustable couplings. On mounts with yoke sights the fourth man is usually unnecessary; the pointer and trainer can ordinarily adjust their sights without leaving their stations.

When the boresighting crew is at its stations, first of all zero the sight-angle and deflection dials. The dials must stay at zero throughout the boresighting procedure described in this section.

Next, train and elevate the gun (in MANUAL) until you see in the boresight telescope the target selected. Then focus it until you get a clear image. Position the gun with the train and elevation handwheels until the crosshairs are on the target point.

If the sighting system is in adjustment, the pointer and trainer will then find their telescopes sighted with their crosshairs on exactly the same point as the boresight telescope. However, if they find that their telescopes aren't sighted exactly that way, the sight mechanisms must be adjusted (with sight angle and deflection still at zero) until they are. The exact method of adjustment depends on the kind of installation. On slide-mounted sights like those of the 3"/50, for example, the telescopes have horizontal and vertical pairs of screws for adjusting the reticle. But on carriage-mounted sights like those of the 5"/38 you loosen and reset adjustable couplings in the linkage between the sight telescopes and the rest of the sight mechanism. (Fig. 16–9 points out their locations on a 5"/38 single mount.)

If the ship is afloat, the boresighting procedure takes into account the ship's pitch and roll. The man at the boresight calls "MARK" as he sees his crosshairs on the target point. The pointer and trainer can at that instant determine exactly how much their sights are off, and in what direction.

Suppose the pointer's telescope is off the target in both sight angle and deflection. First his HORIZONTAL crosshair is adjusted onto target so that it crosses the target at the instant the man at the boresight calls "MARK." When the pointer thinks the crosshair is adjusted on the nose, he also calls "MARK" as the crosshair crosses the

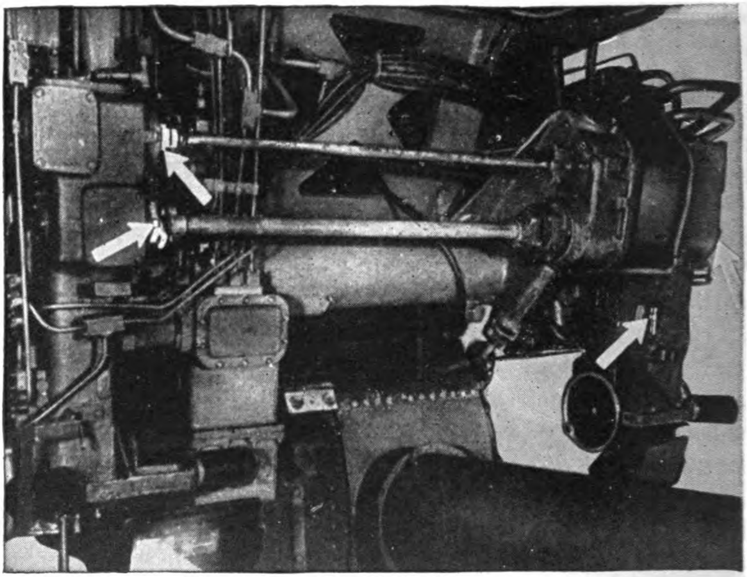


Figure 16–9.—Adjustable couplings for sight adjustment (5"/38).

target. If the pointer and the man at the boresight say "MARK" at the same time, the adjustment is probably OK. If both men repeat "MARK" several times at the same instant, the horizontal crosshair can be considered adjusted.

Then the pointer checks the vertical crosshair. The crew next adjusts the trainer's telescope similarly—but first the vertical crosshair, then the horizontal. Finally, after both telescopes have been adjusted, check the sight setter's dials. They should still be zeroed.

If your mount is fitted with a check sight telescope, you align it on the boresight target in the same way. Since the check sight is coupled to the pointer's telescope, it should be adjusted AFTER the pointer's telescope.

To make sure that all telescopes have been sighted on exactly the same point, rotate the crew among the sights until each man has looked through each of the three telescopes as a check. Before each check, crank sight angle and deflection off zero and back on again to verify the accuracy of the zero setting.

The final check is to insert the muzzle disc and make sure the boresight telescope is still aligned with the bore axis. Then remove the boresighting equipment and stow it in its container. Don't forget the muzzle disc. This is precision equipment, to be stowed in the place and in the manner prescribed.

Except for the details of focusing the boresight telescope and checking alignment with the muzzle disc, this boresighting procedure applies to ALL boresights used with targets at a range of 1,000 yards or more.

BORESIGHTS WITH SELF-CONTAINED OPTICS

In preceding sections we have taken up in detail boresighting gear and procedures for boresighting generally, and for breech-bar boresights particularly. Most older weapons 3-inch and larger use this type of boresight and substantially the same procedure. But most newer weapons and all machine guns use boresights with self-contained optics. These are of various design. Each type of boresight with self-contained optics is usable with only one caliber of gun—and sometimes with only one or two marks of gun of a caliber. Thus, 5"/54 boresight cannot be used with 5"/38 guns.

We'll take up individually each of the self-contained optics boresights (up to 5-inch) you're likely to come across, describing them and how they're installed and removed. You already know the boresighting procedure; it won't be repeated.

20-mm Boresights

The 20-mm AA machine gun is normally used with lead-computing sights like the Mk 14 and Mk 20. Boresighting it involves adjusting the line of sight through the mounting bracket for the sight, before adjusting the LOS of the sight itself. This is done when the gun is first installed on its mount and before the sight is installed. After the sight is mounted, it is lined up with the bracket.

Since maintenance of Mk 14, Mk 20, and other lead-computing sights is part of the duty of the FT, you will usually work with an FT when boresighting the 20-mm gun and installing the sight.

The line of sight through the bracket for the Mk 14 sight is established by a BORESIGHT TUBE inserted in the right-hand support rod hole of the mounted bracket (fig. 16–10). The tube has a small hole at each end and a reticle to define the line of sight. The axis of the bore may be established by either of two standard boresighting instruments. These are:

1. The 20-mm boresight tool.
2. The 20-mm boresight Mk 3 Mod 0.

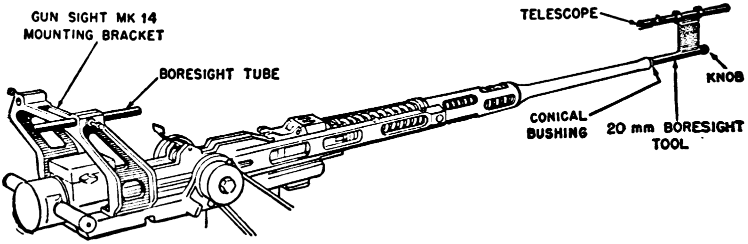


Figure 16–10.—20-mm boresight tool installed.

Let's take up the BORESIGHT TOOL first.

Figure 16–10 shows the boresight tool installed in the gun barrel and the boresight tube installed in the Mk 14 sight bracket. The tool consists of a tubular rod or MANDREL with a telescope adapter secured to it by a steel web. In the adapter is mounted a telescope of the type mounted on snipers' rifles. The telescope reticle defines the line of sight. The telescope is held rigidly parallel to the mandrel.

The mandrel has an expansion nut at the after end, a conical bushing about the middle, and a knurled knob at the forward end. The expansion nut can be made to expand or contract by turning the knob. When correctly installed in the gun bore, the mandrel will be accurately centered therein, and the telescope will then be parallel to the axis of the bore. When you sight through the telescope, you will sight not along the axis of the bore, but parallel to it. The offset is too small to be important.

Before installing the tool, turn the knurled knob counterclockwise, and press the bolt in to release the plunger from the expansion nut. To install, insert the mandrel, expansion nut first, into the muzzle until the conical bushing fits snugly into the bore. Then turn the knurled knob clockwise to spread the nut and hold the mandrel in position.

To remove the tool, turn the knurled knob counterclockwise to loosen the nut, and draw the tool out.

The 20-mm BORESIGHT 3 MOD 0 (fig. 16–11) consists of three units—a REAR SIGHT ASSEMBLY to mount in the breech, a FRONT SIGHT ASSEMBLY for the muzzle, and an ENTERING TOOL for installing the front sight assembly.

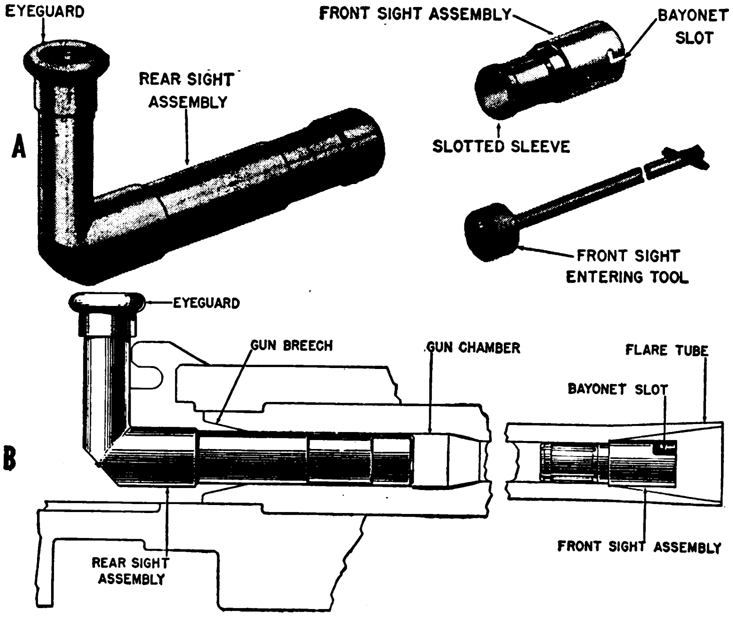


Figure 16–11.—20-mm boresight Mk 3 Mod 0. A. Components. B. Assembled in gun.

The rear sight has a small hole through which you can look by peering downward into a small mirror. The front sight contains a reticle, visible when you look into the mirror through the bore. This boresight establishes the line of sight along the bore axis.

The Mk 3 Mod 0 boresight contains no lenses, and does not magnify the target or make it appear closer than it does to the naked eye. The image you see is INVERTED (upside down), but NORMAL (which means that it is NOT reversed from left to right). Remember to make allowance for the inverted image when getting the crosshairs on target.

To install the boresight, remove the magazine, if one is mounted, cock the gun, and set it at SAFE. Clean the gun bore and chamber and the parts of the boresight that will bear against them.

To install the rear boresight assembly, grasp it by the eyepiece, and insert it, tilting its body into the magazine opening in the breech casing. When it is aligned with the chamber, slide it forward and level it out. Don't force it, but make sure it fits snugly in the chamber. The eyepiece should extend straight upward when the assembly is installed.

Before trying to install the front sight assembly into the muzzle, insert and secure the entering tool in the bayonet slots in the assembly. Then, holding the tool by the handle, insert the front sight into the muzzle. The after part of the front sight assembly is a slotted sheet-metal sleeve, which is compressed as you push the sleeve into the bore. Push the front sight into the bore until the tapered bearing surface takes up on the muzzle. Withdraw the tool by turning it clockwise while pulling it out of the muzzle.

Look into the rear sight to check the crosshairs. To adjust the reticle so that the crosshairs are vertical and horizontal, insert the entering tool and twist the entire front sight assembly.

To remove the front sight assembly after boresighting, insert the entering tool in the bayonet slots and turn it counterclockwise while drawing the front sight out of the muzzle. To remove the rear sight assembly, grasp the eyepiece and rock it carefully from side to side while drawing it backward. If it sticks, you may find it helpful to insert a short stick of soft wood between the eyepiece and the face of the gun breech, then to apply steady pressure against the eyepiece where it joins the body, meanwhile working the entire assembly from side to side.

If neither the boresighting tool nor the Mk 3 boresight is available, you can boresight the 20-mm gun by using a jury rig made up of an empty cartridge case, a bore-clear mirror, and a couple of wires. Here's how:

1. Bore a 3/32-inch hole through the primer end of the case. (Be sure the case you use is not dented or distorted, and that it doesn't have a live primer in it.) Cock the gun, set at SAFE, and insert the case all the way into the chamber.
2. The maintenance tools issued to 20-mm batteries include a small mirror called the BORE CLEAR MIRROR. This mirror mounts in front of the breechblock face and can be adjusted to give a clear view of the bore for inspection. But it can also be used for boresighting. Install the mirror and adjust it to give a clear view of the gun muzzle through the hole in the cartridge case base.
3. For crosshairs, use a couple of fine wires secured over the muzzle. Line up the wires by eye horizontally and vertically, so that they intersect in the center of the muzzle. If you're careful, you can line up the wires to be sufficiently accurate for the purpose.

Your jury-rig boresight is now ready for use.

The only point to note concerning the dismantling of the boresight is the removal of the cartridge case. You can push it out by inserting the gun-cleaning rod through the gun muzzle.

40-mm Boresights

As with the 20-mm AA gun, there are two models of boresight for the 40-mm gun—the Mk 1 Mod 0 and the Mk 2 Mod 0.

The Mk 1, used only with twin and quad mounts, is a complete boresight with self-contained optics, including a mirror, reticle, and telescope optical system. The Mk 2 boresight is simpler—merely a mirror with adapter to position it in the gun breech. It can be used with single mounts as well as the twins and quads. Let's take up the Mk 1 first.

The Mk 1 Mod 0 40-mm boresight is composed of four principal components, illustrated in figure 16–12:

1. Rear sight assembly (eyepiece, mirror, reticle, and part of the telescope optical system).
2. Front sight (muzzle) assembly which has a lens to complete the telescope optical system.
3. Retaining spring assembly, which supports the rear sight unit when installed in the breech.
4. Extracting plug assembly, for inserting and removing the front sight.

The equipment furnished with the boresight includes LIGHT STOP and FILTERS. The light stop is a metal plate or diaphragm with a small hole. When inserted into the line of sight, it reduces the amount of light transmitted and makes it easier to focus the boresight. The filters reduce the amount of light transmitted and make it easier to see a distant target through haze. Most boresights are equipped with similar accessories to be used as needed.

The image you see in the eyepiece of the 40-mm boresight Mk 1 Mod 0 is erect (top side up) but reversed from left to right.

To install the rear sight unit, open and secure the top door of the gun, and lower and secure the breechblock. The body and eyepiece of the rear sight unit are separately stowed in the boresight case. First lower the body and insert it into the chamber; then assemble the eyepiece to it.

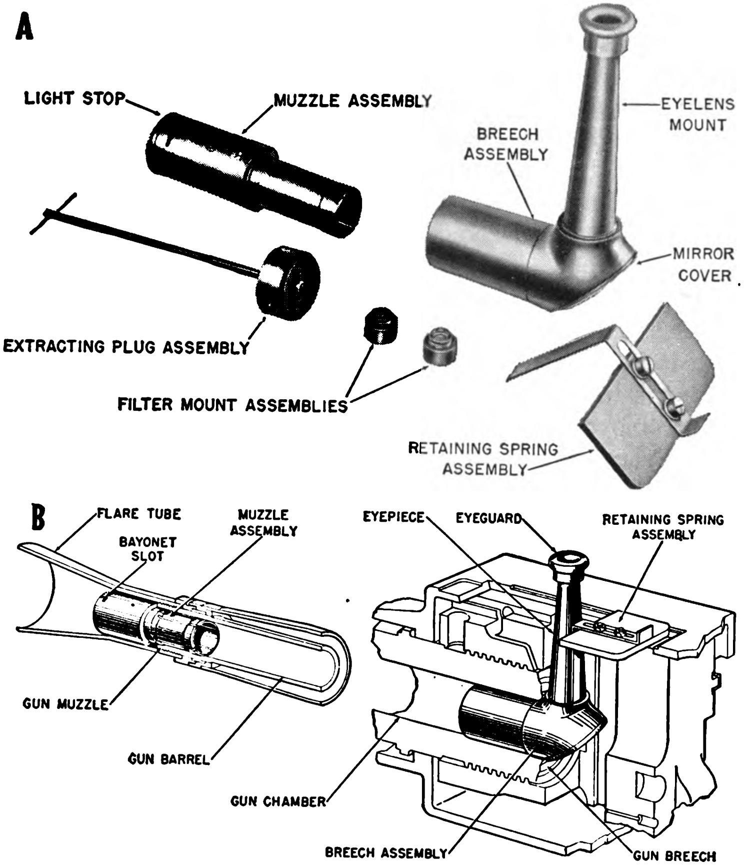


Figure 16–12.—40-mm boresight Mk 1 Mod 0. A. Components. B. Assembled in gun.

The retaining spring assembly holds the rear sight unit securely in place, as figure 16–12B shows. Loosen the two screws at the top of the plate and slide the flat retaining spring back as far as it will go. Insert it behind the breech assembly, slide the spring forward against the eyepiece base, and tighten the screws.

To install the front sight unit, first insert the extracting plug assembly pins into the slots of the sight. Then, holding the extracting tool by its handle, insert the sight unit into the muzzle. The after end of the sight unit is a slotted sheet-metal sleeve that compresses when inserted into the muzzle. Press it into the bore until its tapered bearing surface is seated against the muzzle. Seat it firmly, but don't use force. Then turn the extracting plug counterclockwise and withdraw it. If the front sight unit is squarely inserted, no further adjustment is necessary.

To dismount the front sight assembly, insert the extracting plug into the slots, and turn it clockwise as you push it in. Then, continuing to apply a clockwise twist, draw the tool and front sight out.

To remove the rear sight unit, first loosen the screws on the retaining spring assembly, slide the spring back,

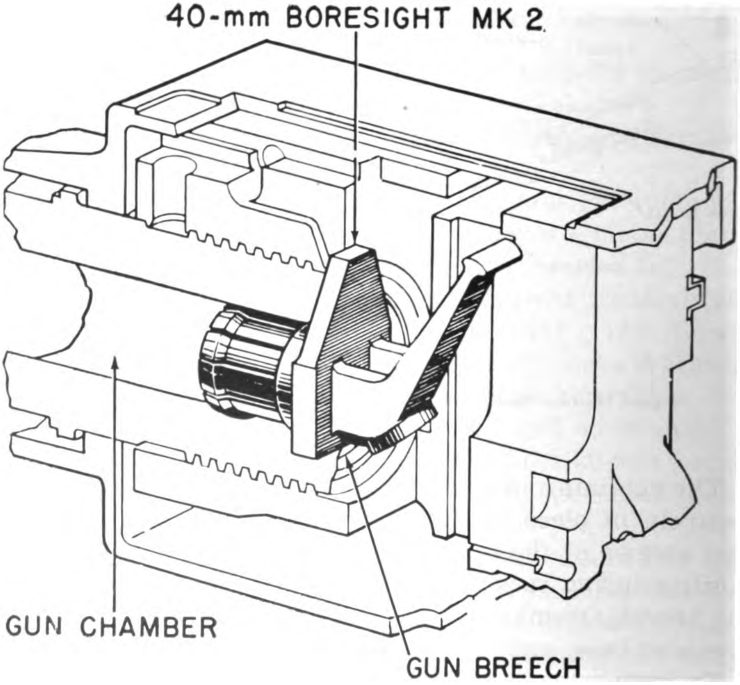


Figure 16–13.—40-mm boresight Mk 2 Mod 0 installed.

and remove it. Next, take out and stow the eyepiece. Then grasp the rear of the body of the rear sight and draw it backward and upward to remove. Last, close the top door on the slide and raise the breechblock.

The Mk 2 Mod 0 40-mm boresight is, as you already know, simply a mirror in an adapter that fits into the gun breech (fig. 16–13). It has no reticle, though you can improvise one by stretching two pieces of wire or string —one vertically and one horizontally—across the muzzle of the gun, positioning them by eye. If you set up the "crosswires" carefully, you can do reasonably accurate work with this boresight.

The Mk 2 boresight is easily inserted into and removed from the 40-mm breech. Be sure to secure the top door up and the breechblock down while the boresight is in use.

3-Inch Boresights

The standard boresight for 3-inch mounts Mk 22 and earlier is of the conventional breech-bar type. Let us therefore go on to consider the 3-inch boresight Mk 30 Mod 1, pictured in figure 16–14.

The Mk 30 Mod 1 boresight is used on 3-inch RF mounts

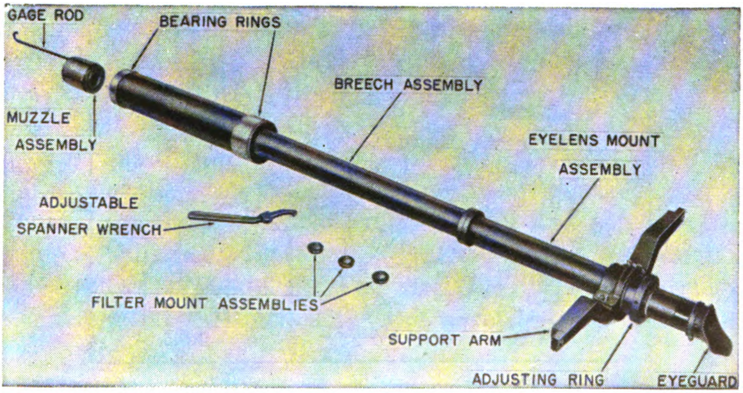


Figure 16–14.—3-inch boresight Mk 30 Mod 1.

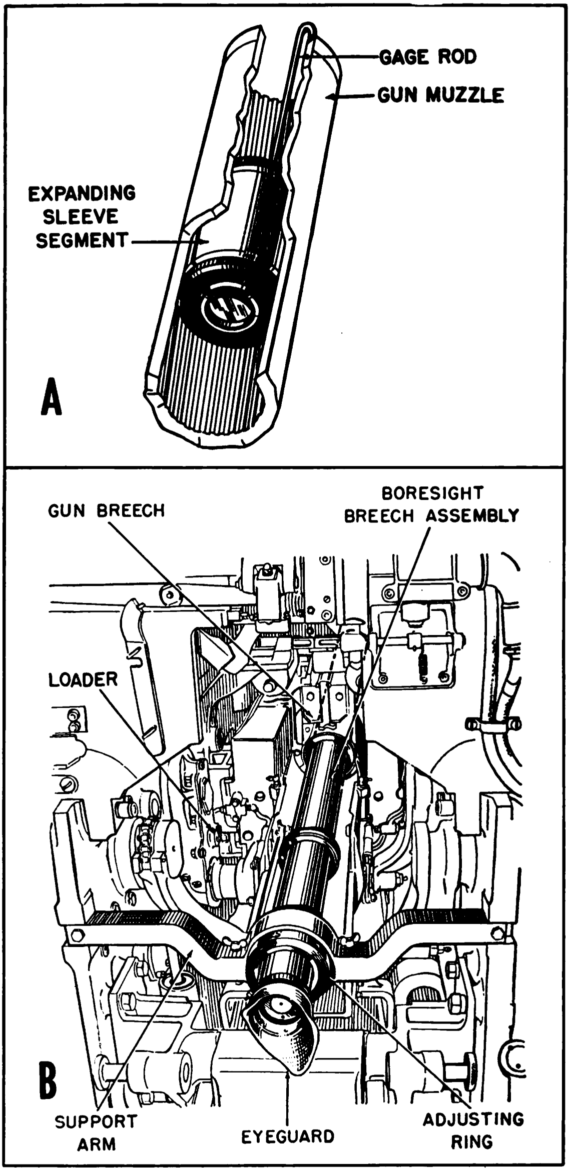


Figure 16–15.—3-inch boresight Mk 30 Mod 1, installed.
A. Muzzle assembly (front sight).
B. Breech assembly (rear sight).

Mks 27, 30, 33, and 34. As with the 40-mm Mk 1 boresight, the Mk 30 consists of a rear sight unit and a front sight unit, both containing optical elements that, when installed, convert the 3-inch barrel into a king-size telescope. The front sight mounts in the gun muzzle. The rear sight, which contains the reticle, has bearing rings at the forward end that fit into the chamber, and a SUPPORT ARM or BRACKET (much like a breech bar) that supports its after end. The image you see through this boresight is erect and normal, like the one in a spyglass. There is no mirror; it's a straight telescope.

CAUTION: Installing the 3-inch boresight Mk 30 on a 3-inch RF gun is more complicated than boresight installation is on most other mounts. DON'T attempt it unless you are familiar with the gun and its mechanism, particularly the loader, both from actual experience and from having studied the OP's.

Here is the procedure for installing the boresight breech assembly (fig. 16–15A):

1. Elevate the gun to 10° to 15°, but not to more than 25°, or the case chute will foul the boresight. For the safety of the man at the boresight, install cribbing to prevent gun elevation higher than this. Use the power drive in local control to position the gun, both in this step and in actual boresighting. Because of the mass of the loader and slide, it's difficult to stop the gun by hand once you've started it moving in elevation; only with the power drive will you be sure of adequate braking.
2. Open the breech, and lash the breech mechanism operating lever to the buffer bar to secure.
3. Open the loader controller switch and tag it with a warning: "DANGER! DO NOT CLOSE SWITCH OR OPERATE LOADER." The switch must remain open and tagged until after the boresight has been removed.
4. Install the loader handcrank and work the loader until the tray is against the lower buffer. This puts

the tray below the boresight tube. Remove the shell carriage and release the tray-shell finger mechanism to clear a passage for the boresight.

5. Assemble the support arm to the after end of the telescope. Before tightening the thumbscrew, align the index mark on the cap with the body.
6. Insert the boresight breech assembly through the loading assembly from the rear until the first bearing ring enters the breech. Push the latch lever to one side to clear the entrance to the breech.
7. Slide the boresight breech assembly forward into the breech until its rear bearing ring centers and the unit takes up snugly in the breech. At the same time, align the support arm, with bearing cap up, until it seats snugly in the two notches at the rear of the loader side plates.
8. Rotate the adjusting ring to seat both sides of the support arm firmly in the notches. But don't seat them too tightly; if you do, the assembly may be drawn from its seat in the gun chamber.
9. Tighten the two retaining bolts.

The boresight muzzle assembly is installed this way:

1. First assemble the muzzle assembly to the gage rod. Back out the setscrew that enters the hole tapped for the gage rod until the tip of the screw clears the hole. Then insert the gage rod, align the hole in it with the setscrew, and tighten the screw.
2. Insert the assembly into the muzzle, gage rod out. Press the assembly in until the face of the gage rod hook contacts the muzzle face (fig. 16–15B).

Leave the gage rod in the muzzle unit until you have withdrawn the unit from the gun. It doesn't interfere with boresighting.

The boresighting procedure is similar to the one already taken up for the 5"/38, except that since the 3"/50 has slide-mounted sights, there is no elevation transmission mechanism to check for lost motion. It's necessary to check for lost motion only in the sight-setting mechanism.

On twin 3-inch mounts, first boresight the right gun with the open and telescopic surface sights. Then shift control from surface to AA and boresight the left gun with the ring sight.

The Mk 30 boresight has a light stop and filters. The light stop can be used to clarify the image of a target, but the boresight itself can be focused for nearby targets by pulling the front sight unit forward with the gage rod. Use the table below as a guide to focusing. The left column of the table gives ranges to target in feet; the right column gives distance in inches between gage-rod hook end and muzzle face for the best focus at the corresponding range.

Range (feet)	*Pull out gage rod (inches)*
1,800	0
1,200	1
600	2
400	3
300	4
250	5
210	6
180	7
160	8
145	9

After boresighting is finished, remove the muzzle and breech units. To remove the muzzle unit, draw it out by the gage rod. As the muzzle unit emerges from the muzzle, grasp it firmly and pull it out the rest of the way. Be careful not to bend the gage rod. Loosen the setscrew and remove the rod before stowing.

To remove the breech assembly, first free it from the chamber by turning the adjusting ring clockwise with the spanner wrench. Then remove the support arm retaining bolts and slide the entire unit out through the loading mechanism. Dismount the support arm from the breech assembly and stow. Coat the bright surfaces of the bearing rings with the proper grease (at present identified by the symbol 14G8). Stow the parts.

Boresight for 5"/54 Guns

The 5-inch boresight Mk 35 Mod O is a self-contained optic type intended for 5"/54 mounts Mk 39. The boresighting procedure, once the instrument is installed, is exactly the same as for the 5-inch boresight Mk 32 Mod 1, discussed earlier in this chapter.

Mk 35 Mod 0 consists of a breech unit (rear sight assembly) and a muzzle unit (front sight assembly). (See fig. 16–16.) The muzzle unit contains a lens, and the breech unit contains other lenses, the reticle, and a mirror. When installed, the boresight converts the gun into a telescope, but you look down into the breech as in the Mk 1 boresight of the 40-mm gun. The image you see in the eyepiece of the Mk 35 is erect but reversed from right to left.

To install the breech unit (fig. 16–16B):

1. Open the breech, using the operating handle, and secure. The rammer spade, however, need not be secured.
2. Lower the breech unit into the tray and slide it forward. Be sure the stop arm on the unit (fig. 16–16B) is UP. Push the unit forward until it seats in the chamber. Be especially careful, at this stage, not to damage the reticle at the forward end of the assembly.
3. When the assembly is fully seated in the chamber, drop the stop arm in front of the rear face of the after breech-plug groove (fig. 16–16B). If there is vertical scribe mark on the housing, use it as a guide to adjust the sight to an accurate vertical.

Before installing the muzzle unit, assemble the gage rod. The gage rod has two sections, one hooked and one straight. First, remove the setscrew from the front flange of the muzzle assembly and insert the solid end of

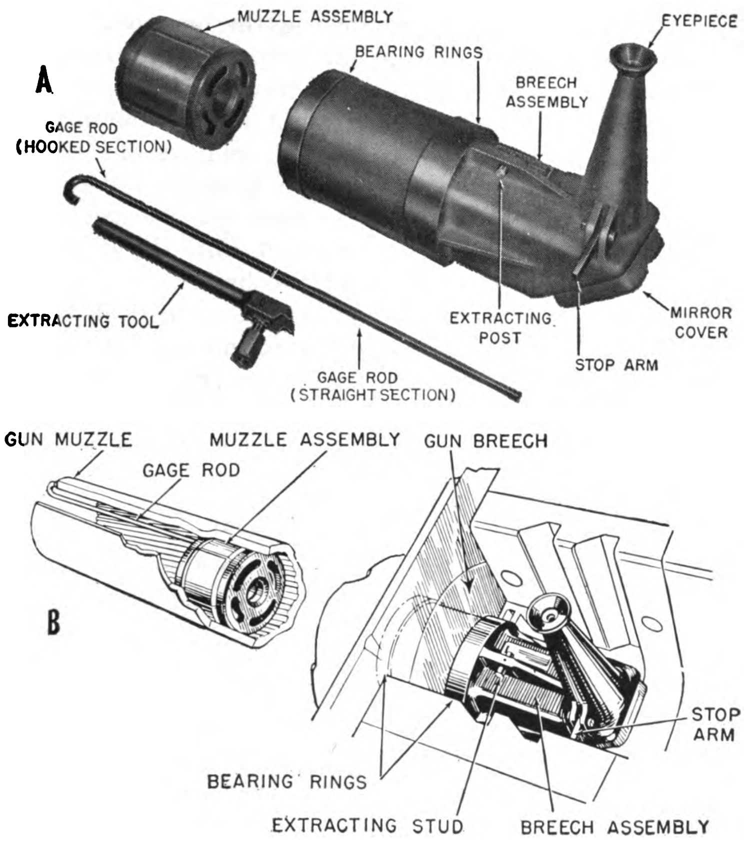


Figure 16–16.—5-inch boresight Mk 35 Mod 0. A. Components. B. Assembled in gun.

the straight rod section into the gage rod hole. Line up the hole in the side of the rod with the setscrew hole, and then insert and tighten the screw. Last, screw the hooked section of the rod onto the one already mounted.

Now install the muzzle assembly. Hold it by the body, NOT by the gage rod, and carefully insert it into the muzzle, gage rod out. Push it in with the rod until the rod hook contacts the muzzle face.

To check the optical accuracy of the boresight, rotate the muzzle unit 180°. If the intersection of the crosshairs as seen through the eyepiece appears to shift two minutes of arc or more, remove the boresight and use another.

After boresighting is completed, remove the muzzle unit by reversing the installation procedure described above. For the breech unit, however, use the special EXTRACTING TOOL illustrated in figure 16–16A. First, lift the stop arm up until it's clear of the breechblock groove. Then hook the extractor tool onto the forward side of the post or stud provided for it and drop the anvil of the tool onto the face of the breech. Press forward on the handle of the tool to unseat the breech assembly. Lift the breech assembly out. Be careful of the reticle on its forward face.

Boresight for 5"/38 Guns

The Mk 38 Mod 1 boresight, a self-contained optic type, can be used on all 5"/38 guns in place of the Mk 32 Mod 1 (the breech-bar type discussed earlier in this chapter). Mk 38 has an advantage over Mk 32 in that it requires none of the muzzle disc alignment and optical checking necessary with breech-bar boresights. Once either Mk 32 or Mk 38 is installed and lined up, however, the boresighting procedure is exactly the same as the one described in this chapter.

The procedure for installing and checking the Mk 38 boresight is exactly the same as for the Mk 35 described in the preceding section. The main difference between them is that the gage rod of the Mk 38 is shorter and comes in one piece. To install it in the muzzle assembly of the boresight, unscrew the setscrew in the assembly and insert the straight end of the rod into the mounting hole. Line up the hole in the rod with the setscrew; then reinsert the setscrew and tighten.

The procedure for removing Mk 38 from the gun after boresighting is also the same as for Mk 35. The extracting tool provided works the same way.

BORESIGHT MAINTENANCE

All boresights are precision equipment and require the care precision equipment deserves. Remember always that there are only two places that any boresight should be—either in the gun or stowed in its carrying case. If it's not in use—stow it. If it is in use, look through it, but don't lean on it.

Here are some pointers on the proper care of boresights:

1. Boresight gear in its containers should be stowed in a cool, dry place. Sudden changes in temperature, especially overheating, are hard on all precision optical instruments.
2. Some boresight components, like muzzle discs, are large and clumsy to handle. But don't forget that these are precision units also. They have been accurately machined and fitted; if you treat them rough they'll give rough results.
3. Keep boresight gear clean. All parts except optical surfaces should be wiped both before and after use with a clean dry cloth. This is especially true of bright machined metal surfaces that bear against the muzzle or chamber of the gun. But DON'T use abrasives. Make sure the muzzle and chamber surfaces of the gun are clean too.
4. Lenses and other optical surfaces should be cleaned by wiping (NOT scrubbing) with dry lens tissue. Don't use anything else; it's better to leave optical surfaces dusty than to clean them with the wrong material. Leave stubborn spots for the Opticalman to deal with. Don't try to wipe away the purplish coating that you'll find on many optical surfaces; the coating improves optical efficiency, and shouldn't even be scratched.
5. Clean rubber eyeguards by washing in clean soapy water.

6. If there is anything wrong with the boresight, don't use it. Turn it in for repair by an optical shop, and use another. You can consider a boresight unserviceable if:
   - a. There is a serious optical error noted as a result of the routine checking discussed earlier in this chapter.
   - b. The reticle is out of focus or out of line and cannot be adjusted by any of the regular adjusting devices on the instrument.
   - c. There are any cracks in the metal or optical parts.
   - d. The instrument seems bent or distorted or cannot be made to fit into its place without forcing.
   - e. There is any evidence of moisture inside the instrument.
   - f. The target cannot be brought into focus. Before concluding the instrument is out of order, however, be sure it's correctly installed and the target is not too close. Many boresights with self-contained optics can be focused on relatively distant targets, but to improve focusing at shorter ranges, use a light stop, or adjust the gage rod in accordance with instructions.

Except for keeping them clean, using them properly, and stowing them in the way prescribed, you as a Gunner's Mate or striker will not have much to do with maintenance of boresights. You are not responsible for lubricating them, although you may have to apply some 14G8 grease to bearing rings to keep them bright. If you do apply the grease, use it sparingly, and don't use anything else. Don't apply ANYTHING to optical surfaces.

TRAMMING

When you measure gun elevation and train, you specify the angle in degrees and minutes between the axis of the bore and:

1. A plane parallel to the roller path of the director (for elevation angle).
2. A plane through the centerline of the ship and perpendicular to the plane of the director roller path (for train angle).

This may sound complicated, but if you remember the chapter on fire control earlier in this course, you'll find it easier than it sounds.

To make train and elevation angle measurements accurate, gun mounts and turrets must be very carefully aligned when they are installed. To KEEP such measurements accurate, the Gunner's Mate checks the dials on his mount that register angle of train and elevation with the actual position of the mount by means of a TRAM and TRAM BLOCKS.

The basic idea of tramming is to position the gun at a known angle of elevation or train (depending on which you're checking), then see that the elevation-angle or train-angle dials register exactly the angle the mount is elevated or trained to. There is only ONE elevation angle

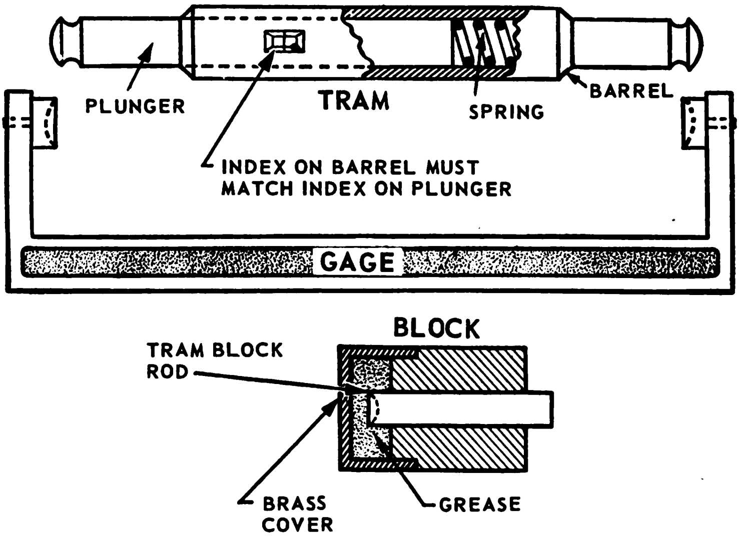


Figure 16–17.—Tram, tram gage, and tram block (detail).

and one train angle at which any mount can be trammed. These angles are recorded in the battery or mount log.

Tram blocks are steel blocks welded or bolted to the mount in pairs, one pair for tramming in elevation, and the other for tramming in train. As you can see in figure 16–18, one of the pair of blocks for checking elevation is welded to a part of the mount that elevates (the slide weldment); the other is welded to a part that does NOT move in elevation (the carriage cheek). Similarly, one of the pair for tramming in train is welded to a part that moves in train (the base ring), and the other to a stationary part (the stand) secured to the deck.

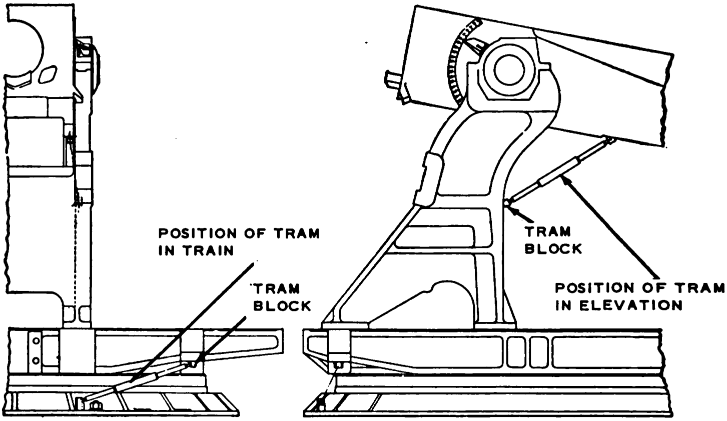


Figure 16–18.—Tramming a 5"/38 single mount in elevation and train.

A typical tram block for a 5"/38 mount is shown in cross section in figure 16–17. Imbedded in the block is a short steel pin whose outer end is cupped to take the tram. The tram block face is covered with a metal cap and packed with grease to prevent corrosion. The block is uncovered only for tramming, and is repacked when the cover is replaced.

The tram itself has two rounded ends. One is part of the body or BARREL, but the other is part of the spring-loaded SLEEVE or rod that can move within the barrel. A small window-like hole in the barrel has an index line scribed across it. A line scribed on the sleeve can be matched up with the barrel index line by moving the sleeve in the barrel.

When not in use, the tram is kept stowed in its container with a TRAM GAGE. The tram fits between the cupped ends of the gage. When it is in the gage, the scribe marks on barrel and sleeve should line up exactly. This verifies that the tram is the right length.

Here are the main steps for tramming in train:

1. Remove the tram from the gage, first checking to be sure that the gage indicates the tram is OK.
2. Set the mount parallax indicator (if any) at zero. Train the gun until the train-angle indicator shows that the mount is at the approximate train angle for tramming. The value of the angle may vary for different mounts. You should be able to find the exact value of the angle entered in the battery log, or it may be inscribed on the tram blocks themselves.
3. Uncover the tram blocks for tramming in train. Clean away excess grease and seat the ends of the tram FIRMLY in the pins of the blocks. Train the mount if necessary to do this.
4. With the tram ends seated, train the mount CAREFULLY in manual to compress the tram until the scribe marks on barrel and sleeve line up exactly. The mount is now trammed in train.

This step sounds easy, but requires caution. If the tram hasn't been properly seated in the blocks, or if the gun isn't moved carefully while the tram is in place, the tram can snap out with enough force to cause injury. Don't let it happen to you. This caution applies to tramming in elevation as well as in train.

5. Take a reading on the train-angle indicator dial. It should agree exactly with the value you were given

in step 2 above. If it does not, the indicator needs adjustment. The adjustment procedure varies with different mounts, and is not described here.

Tramming in elevation is similar to tramming in train. However, on mounts equipped with roller path compensators, you'll have to train the gun to a point at which roller path compensation is zero. There are in theory two such zero points in the roller path of every mount, but many mounts that cannot train a full 360° will actually have only one usable point of zero compensation. The exact train angle at which the point is located should be recorded in the fire-control log. Your gunnery officer or chief can tell you what it is, or show you how to read the roller path compensator so that you can find it yourself.

Once you've trained the mount to the correct angle, the procedure in elevation is similar to the one for tramming in train, except that you use the elevation tram blocks, controls, and angle indicator. The same tram is used in both cases.

In tramming, a crew of two is enough—one man at the controls, one at the tram.

The tram and tram blocks pictured in figures 16–17 and 16–18 are the type you will most often come across. Older mounts may have tram marks instead of blocks, and a one-piece nonadjustable tram with accurately machined points that you register with the marks when the mount is trammed.

Tramming to check the accuracy of train and elevation indicators is your responsibility as a Gunner's Mate. Tramming is used also in director checking and in aligning sights. In these jobs you work with your chief and with the Fire Controlmen, but the essential tramming operation remains the same.

SUMMARY AND STUDY REFERENCES

In this chapter you have learned basic techniques (boresighting and tramming) of battery alignment that you as a GM2 are supposed to know. This is, of course, far from the whole story on battery alignment. Since you will be expected to know a good deal about the subject in order to earn your rate as Chief Gunner's Mate, you should learn as much about it as you can. Some of the books you can study on the subject are:

1. *Fire Control Technician 1 & Chief* Vol. 2, NavPers 10177
2. *Alignment of Ordnance Installations,* OGS 12
3. *Alignment of Ordnance Installations on Board Ship,* OP 762. (This book is now under review.)

In the Navy Training Course listed above, you need read, as far as battery alignment is concerned, only those sections that deal with this subject. They will give you the basic information you will need to understand the next two items on the list. OP 762 is the official bible of battery alignment afloat. OGS No. 12 is in some respects a more complete and mathematical discussion, and it covers battery alignment work done in drydock.

Please note that you do NOT have to study the three books listed above in order to qualify for GM2. But you'll find them valuable if you want to step ahead of the bare minimum you need to know for promotion. Look to your chief and your gunnery officer for guidance in just what and when to study.

For more information on boresights, see OP 1449.

CONCLUSION TO THE COURSE

If you started studying this course at the beginning and continued straight through to the end, you have now reached the end—almost. (There's still a quiz to this chapter.) You've surveyed the job of the GM2 from beginning to end, and you've completed a major step in preparation for promotion. But have you done *everything?* Review the discussion in chapter 1 on what you must do for promotion, and then briefly review the whole course. Be sure you're well prepared when the time for the promotion exam rolls around—then go to it!

QUIZ

In each of the following multiple-choice questions, select the ONE BEST answer.

1. As a result of boresighting a gun:
   a. Sight angle and deflection angle are always equal to zero
   b. The axis of the bore and the line of sight through the boresight telescope intersect at the mean battle range
   c. At zero deflection and sight angle the lines of sight through the sight telescopes will intersect the axis of the bore at a specified range, or will be parallel to it
   d. At all deflections and sight angles the lines of sight through the sight telescopes will intersect the axis of the bore at a specified range, or will be parallel to it
2. Which of the following statements can be applied to a breech-bar type of boresight?
   a. The boresight converts the gun type into a giant telescope
   b. The telescope is lined up with the axis of the bore by sighting on a device mounted in the muzzle
   c. The telescope is mounted outside of the bore and parallel to it
   d. The boresight converts the gun into a giant peepsight
3. The very first thing to do before installing any boresight is to:
   a. Open the breech and secure the breech mechanism so that the breechblock cannot close
   b. Clean the chamber so that the boresight can be accurately aligned
   c. Eliminate lost motion in the sight-setting mechanism
   d. Align the telescope with the muzzle disc
4. The main function of the muzzle disc in the breech-bar type of boresight is to:
   a. Aid in testing the boresight telescope for crosshair parallax
   b. Aid in establishing the line of sight of the boresight telescope on the axis of the bore
   c. Aid in lining the boresight telescope up with the target
   d. Protect the boresight telescope from excessive light
5. Which of the following operations is NOT a part of the procedure for checking the sight-setting mechanism for lost motion?
   a. After getting the boresight telescope's crosshairs on target, elevate the gun at least 30° and then depress it until the boresight telescope's crosshairs are once more on target
   b. Set the crosshairs of the trainer's telescope on a target point on the ship and note the sight-angle dial setting
   c. Set the crosshairs of the trainer's telescope on a target point on the ship and note the deflection-angle dial setting

   d. Run the sight-setting mechanism up to maximum sight angle and then crank it back, looking through the pointer's telescope to get its crosshairs on target again

6. During the boresighting of a mount with carriage-mounted sights, the pointer's and trainer's telescopes are adjusted on the same target as the boresight by:
   a. Cranking the sight setter's handwheels and noting the readings on the dials
   b. Elevating and training the mount with the elevating and training handwheels
   c. Resetting the adjustable couplings on the linkage between the sight telescopes and the rest of the sight mechanism
   d. Moving the sight telescope reticles with the adjusting screws
7. The mandrel-type boresight is used with the
   a. 20-mm gun
   b. 40-mm gun
   c. 3-inch gun
   d. 5-inch gun
8. Which one of the boresights with self-contained optics listed below is a straight telescopic unit with NO mirror?
   a. 20-mm Boresight Mk 3 Mod O
   b. 40-mm Boresight Mk 1 Mod O
   c. 3-inch Boresight Mk 30 Mod 1
   d. 5-inch Boresight Mk 38 Mod 1
9. When positioning the 3-inch RF gun for boresighting, use:
   a. Power drive in remote control
   b. Power drive in local control
   c. Power drive in hand control
   d. Manual control, without power drive
10. The main purpose of tramming is:
   a. To check the accuracy of the tram
   b. To make sure that the plane is parallel to the deck and runs through the centerline of the ship
   c. To check the alignment of the director against the bench mark
   d. To check the elevation and bearing dials against known positions of the mount

APPENDIX I

ANSWERS TO QUIZZES

CHAPTER 1

REVIEW AND PREVIEW

1. d.
2. c.
3. a.
4. c.
5. b.
6. a.
7. d.

CHAPTER 2

EXPLOSIVES AND DEMOLITIONS

1. b.
2. a.
3. d.
4. a.
5. c.
6. a.
7. b.
8. b.
9. c.
10. d.
11. a.
12. d.
13. c.
14. c.
15. b.

CHAPTER 3

AMMUNITION

1. d.
2. a.
3. c.
4. c.
5. a.
6. d.
7. c.
8. c.
9. b.
10. a.
11. a.

CHAPTER 4

HYDRAULICS AND HYDROSTATICS

1. d.
2. a.
3. a.
4. b.
5. a.
6. c.
7. b.
8. a
9. b.
10. a.

CHAPTER 5

HYDRAULIC MECHANISMS

1. a.
2. b.
3.

Column A	Column B
(1)	(c)
(2)	(d)
(3)	(b)
(4)	(a)

4. c.
5. b.
6. c.
7. a.
8. b.
9. c.
10. b.
11. d.
12. b.
13. d.

CHAPTER 6

THE FIRE-CONTROL PROBLEM

1. d.
2. b.
3. a.
4. d. It is ALWAYS equally subject to the force of gravity.
5. c.
6. a.
7. c.
8. c.
9. b.
10. d.
11. a.
12. b.

CHAPTER 7

FIRE-CONTROL SYSTEMS AND TECHNIQUES

1. b.
2. c.
3. a.
4. c.
5. a.
6. d.
7. d.
8. a.
9. b.
10. b.
11. a.
12. (b)
13. (b)
14. (b)
15. (a)
16. (e)
17. (b)
18. (b)
19. (b)
20. (e)
21. (b)
22. (c)
23. (d)
24. d.
25. a.
26. b.
27. c.

CHAPTER 8

GUN MOUNTS—20-MM TO 5-INCH

1. (c)
2. (c)
3. (c)
4. (d)
5. (a)
6. (d)
7. (d)
8. (a)
9. (d)
10. (b)
11. (c)
12. (c)
13. (b)
14. (a)
15. (c)
16. (d)
17. (a)
18. (d)
19. (b)
20. (d)
21. (b)
22. (b)
23. (c)

CHAPTER 9

BREECH MECHANISMS

1. c.
2. c.
3. a.
4. d.
5. d.
6. a.
7. c.
8. a.
9. b.
10. d.
11. c.

CHAPTER 10

FIRING SYSTEMS

1. b.
2. d.
3. a.
4. c.
5. a.
6. c.
7. b.
8. a.
9. c.
10. d.
11. a.
12. b.

CHAPTER 11

RECOIL AND COUNTERRECOIL SYSTEMS

1. a.
2. c.
3. b.
4. b.
5. c.
6. d.
7. a.
8. b.
9. c.
10. b.

CHAPTER 12

PROJECTORS AND ROCKET LAUNCHERS

1. a.
2. d.
3. c.
4. b.
5. a.
6. d.
7. a.
8. b.
9. f.
10. f.
11. c.
12. d.
13. d.
14. a.
15. b.
16. a.
17. d.
18. c.

CHAPTER 13

SMALL-ARMS WEAPONS AND LANDING PARTY GEAR

1. b.
2. a.
3. a.
4. d.
5. b.
6. b.
7. d.
8. c.
9. a.
10. b.

CHAPTER 14

SMALL-ARMS AMMUNITION AND MACHINE GUNS

1. b.
2. a.
3. a.
4. d.
5. b.
6. a.
7. c.
8. d.
9. d.
10. b.
11. c.
12. a.

CHAPTER 15

MAINTENANCE

1. d.
2. a.
3. c.
4. a.
5. c.
6. d.
7. d.
8. b.
9. (a) 11.083.
   (b) 13.240.
10. a.
11. c.
12. b.
13. d.
14. c.

CHAPTER 16

BORESIGHTING AND TRAMMING

1. c.
2. b.
3. a.
4. b.
5. a.
6. c.
7. a.
8. c.
9. b.
10. d.

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

GUNNER'S MATES (GM)

Rating Code No. 0600

General Service Rating

Scope

Gunner's mates operate, maintain, overhaul, and repair small arms, rocket launchers, guns, mounts, and turrets; maintain, overhaul, and repair the various electrical, mechanical, and hydraulic systems in guns, mounts, turrets, hoists, and associated equipment; test and inspect, and supervise the handling and stowage of, ammunition and ammunition components; test and adjust electronic amplifiers of gun power-drive systems; inspect and maintain magazines and ammunition stowage spaces; test magazine sprinkler systems; operate and maintain depth-charge mechanisms, projectors, and release mechanisms. When assigned to CB activities, usually serve as armorers.

Emergency Service Ratings

GUNNER'S MATES M (Mounts), Rating Code No. 0601.... **GMM**
Maintain and repair small arms, rocket launchers, 5″ guns and below, and associated equipment; supervise handling and stowage of ammunition and ammunition components; operate and maintain depth-charge mechanisms, projectors, and release mechanisms.

GUNNER'S MATES T (Turrets), Rating Code No. 0602.... **GMT**
Operate, maintain, and repair large guns, turrets, and associated equipment, train and direct turret crews; test, inspect, and supervise handling and stowage of turret ammunition and ammunition components.

GUNNER'S MATES A (Armorers), Rating Code No. 0603 **GMA**
Are usually assigned to CB activities as armorers. Store, issue, and repair field equipment such as small arms, packs, helmets, gas masks, and bayonets; in-

struct personnel in firing and field-stripping small arms; assist mine and bomb disposal personnel in disarming unexploded mines, bombs, and projectiles.

Navy Enlisted Classification Codes

For specific Navy enlisted classification codes included within this rating, see Manual of Navy Enlisted Classifications, NavPers 15105 (Revised), codes GM–0800 to GM–0999.

Qualifications for Advancement in Rating

	Applicable Rates			
Qualifications for advancement in rating	GM	GMM	GMT	GMA
100 PRACTICAL FACTORS				
101 OPERATIONAL				
1. Operate nonpower-driven rocket launchers and projectors if equipment is available	**3**	3	----	3
2. Stow and issue small arms, ammunition, and landing-party equipment	**3**	3	----	3
3. Operate hoists and associated equipment for ammunition supply in own battery	**3**	3	----	----
4. Operate line-throwing gun	**3**	3	----	----
5. Demonstrate ability to man all stations, excluding mount or gun captain, on light or heavy machine gun or dual purpose mount	**3**	3	----	----
6. Locate principal isolation (cut-out) valves and test-operate magazine sprinkler systems in own ship	**3**	3	----	----
7. Demonstrate method of resuscitating a man unconscious from electrical shock and treating for electrical burns	**3**	3	----	----
8. Demonstrate ability to operate or fire pyrotechnics and use associated equipment	**2**	2	----	2
9. Demonstrate use of own ship or station landing-party (infantry) equipment including small arms weapons, and grenades	**2**	2	----	2
10. Operate power-driven rocket launchers and projectors if equipment is available	**2**	2	----	----
11. Demonstrate ability to act as a gun, mount, or rocket mount captain in a main, antiaircraft, or rocket battery	**2**	2	----	----
12. Demonstrate procedures for use of own ship's demolition equipment	**2**	2	----	----
13. Make two-dimensional sketches for job orders	**1**	1	1	1

Qualifications for advancement in rating	Applicable Rates			
	GM	GMM	GMT	GMA
101 OPERATIONAL—Continued				
14. Make ready for firing and operate depth charge battery on own ship	1	1	----	----
15. Demonstrate ability to man all stations and operate all equipment in turret to which assigned	1	----	1	----
102 MAINTENANCE AND/OR REPAIR				
1. Solder electrical connections and watertight seams	3	3	----	3
2. Use drill press, electric and pneumatic power tools, bench grinders, bore and chamber gages, and special hand tools for ordnance equipment maintenance and repair	3	3	----	3
3. Field-strip, clean, lubricate, and reassemble small arms and light machine guns up to and including caliber .50	3	3	----	3
4. Make required inspections of magazines and ammunition	3	3	----	3
5. Clean, lubricate, and make operational tests on ordnance equipment to which assigned, following appropriate check-off lists	3	3	----	3
6. Locate ordnance lubrication fittings, using lubrication charts	3	3	----	----
7. Trace and identify symbols of a circuit on a firing and lighting wiring diagram	3	3	----	----
8. Cut, thread, and tin piping and tubing	3	3	----	----
9. Overhaul, repair, and adjust 20-mm. or 40-mm. gun mechanisms if equipment is available	3	3	----	----
10. Drain and fill hydraulic equipment	3	3	----	----
11. Make tests of firing and lighting circuits, using meggers and test lamps	3	3	----	----
12. Overhaul, repair, and adjust small arms and light machine guns up to and including caliber .50	2	2	----	2
13. Overhaul, repair, and adjust a breech mechanism on a gun not exceeding 5-inch	2	2	----	----
14. Overhaul, repair, and adjust nonpower-driven rocket launchers and projectors	2	2	----	2

Qualifications for advancement in rating	Applicable Rates			
	GM	GMM	GMT	GMA
102 MAINTENANCE AND/OR REPAIR—Continued				
15. Interpret mechanical and hydraulic schematic and ordnance drawings	2	2	----	----
16. Identify symbols and trace circuits on electrical schematics and wiring diagrams	2	2	----	----
17. Use bore erosion gages	2	2	----	----
18. Boresight guns and make necessary adjustments to sight mechanisms	2	2	----	----
19. Test firing cut-out devices and mechanical fuze-setting devices for proper operation	2	2	----	----
20. Make electrical tests using voltmeters, ohmmeters, and multimeters, and perform authorized maintenance of gunnery electrical circuits in power and control equipment in mounts or turrets, and hoists, excluding internal maintenance of electronic components	1	1	1	----
21. Test, adjust, and make repairs to recoil, counterrecoil, and gas ejector systems	1	1	1	----
22. Overhaul, repair, and adjust power-driven rocket launchers and associated equipment if available	1	1	1	----
23. Conduct preparations of a gun or mount and associated equipment for firing	1	1	1	----
24. Prepare for firing and make shipboard tests of rocket, projector, and depth charge ammunition	1	1	----	----
25. Make operational adjustments, test inputs and outputs, and replace tubes in power-drive amplifiers	1	1	----	----
26. Overhaul, repair, and adjust all mechanical and hydraulic equipment in a turret or mount	C	C	C	----
27. Make casualty analysis and direct repair of all mechanical and hydraulic gun equipment	C	C	C	----
28. Test and adjust, and overhaul and repair, indicator and receiver regulator equipment used in hydraulic power-drive control systems	C	C	C	----
29. Conduct preparation of a battery or turret for firing	C	C	C	----

	Applicable Rates			
Qualifications for advancement in rating	GM	GMM	GMT	GMA
103 ADMINISTRATIVE AND/OR CLERICAL				
1. Record required information in battery and magazine logs	**3**	3	----	3
2. Train personnel in field-stripping and firing small arms	**2**	2	----	2
3. Prepare naval shipyard or tender work request or job order	**2**	2	----	----
4. Train battle station crews in operation, safety precautions, and casualty procedures of guns, mounts, or rocket mounts	**2**	2	----	----
5. Maintain supplies and spare parts and obtain replacements	**1**	1	1	1
6. Maintain ordnance histories	**1**	1	1	1
7. Train battle station crews in turret operation and safety precautions	**1**	----	1	----
8. Prepare reports required by the gunnery or ordnance department	**C**	C	C	C
9. Prepare loading and stowage plans for ammunition and ammunition components	**C**	C	C	C
10. Maintain a Current Ship's Maintenance Project (CSMP)	**C**	C	C	----
200 EXAMINATION SUBJECTS				
201 OPERATIONAL				
1. Methods of lighting, cooling, ventilating, and sprinkling magazines	**3**	3	----	3
2. Safety precautions to be observed in the handling and stowage of explosives	**3**	3	----	3
3. Color codes and markings used for projectile identification. Types of projectiles and projectile components	**3**	3	----	----
4. Methods of setting mechanical fuzes	**3**	3	----	----
5. Safety precautions applied to handling and firing of rocket ammunition from nonpower-driven rocket launchers	**3**	3	----	3
6. Principles of function and purpose of firing cut-out devices	**2**	2	----	----
7. Characteristics of projectiles, projectile components, bursting charges, propellants, primers, fuzes, and ship pyrotechnics	**2**	2	----	----

Qualifications for advancement in rating	Applicable Rates GM	GMM	GMT	GMA
201 OPERATIONAL—Continued				
8. Principles of operation of amplidyne motors and generators used in mount power drives	**1**	1	1	----
9. Characteristics of gun, rocket, projector, and depth charge ammunition	**1**	1	1	----
10. Methods of installing pistols and launching depth charges. Depth charge safety precautions	**1**	1	----	----
202 MAINTENANCE AND/OR REPAIR				
1. Soldering methods and materials used for electrical connections	**3**	3	----	3
2. Information obtained from lubrication charts and precautions to be observed in lubricating ordnance equipment	**3**	3	----	3
3. Construction and operating principles of .45-caliber pistol and .30-caliber M1 rifle	**3**	3	----	3
4. Application and principles of operation of cams, gear trains, levers and mechanical linkages, pulleys, chains and sprockets, screws, clutches, springs, universal joints, and bearings	**3**	3	----	3
5. Methods and equipment used in electrical tests for continuity, grounds, and short circuits	**3**	3	----	----
6. Types, uses, and care of fittings, gaskets, and packing used in ordnance hydraulic systems	**3**	3	----	----
7. Operating principles of small arms and light machine guns used by the Navy	----	----	----	3
8. Tests and inspections required for ammunition and ammunition components and explosives	**2**	2	----	2
9. Types of information shown on mechanical, electrical, and hydraulic schematics, ordnance drawings, and wiring diagrams	**2**	2	----	----
10. Purpose and methods of boresighting guns	**2**	2	----	----
11. Purpose of bore erosion gages	**2**	2	----	----
12. Principles of operation of breech and firing mechanisms	**2**	2	----	----

Qualifications for advancement in rating	Applicable Rates			
	GM	GMM	GMT	GMA
202 MAINTENANCE AND/OR REPAIR—Continued				
13. Applications and principles of operation of check, needle, and spool valves; Bourdon gages; gear, vane, and axial piston pumps and motors; work cylinders; and accumulators. Knowledge of the differential area principle and the distinction between simple and compound valves	**2**	2	----	----
14. Principles of operation and purpose of recoil and counterrecoil systems. Purpose of gas ejector systems	**2**	2	----	----
15. Construction of small arms and light machine guns	----	----	----	2
16. Types and construction of small arms ammunition	**2**	2	----	2
17. Purpose and application of voltmeters, ohmmeters, and multimeters	**1**	1	1	----
18. Functional relationships of components of ordnance hydraulic systems	**1**	1	1	----
19. Method of plotting a firing cut-out cam	**1**	1	1	----
20. Methods and purpose of battery alinement afloat	**1**	1	1	----
21. Operating principles of rocket motors and arming of rocket fuzes	**1**	1	----	----
22. Types and characteristics of construction explosives used in CB activities and safety precautions for their handling and stowage	----	----	----	1
23. Purpose and method of conducting surveillance tests of smokeless powder	**C**	C	C	----
24. Characteristics and use of indicator and receiver regulator synchros and methods of setting to electrical zero	**C**	C	C	----
25. Method and purpose of star gaging	**C**	C	C	----
203 ADMINISTRATIVE AND/OR CLERICAL				
1. Purposes and types of entries made in battery and magazine logs	**3**	3	----	3
2. Type of information found in OP's	**3**	3	----	3
3. Functions of various companies of a Construction Battalion	----	----	----	3
4. Procedures for requisitioning spare parts and standard stock items	**1**	1	1	1

Qualifications for advancement in rating	Applicable Rates GM	 GMM	 GMT	 GMA
203 ADMINISTRATION AND/OR CLERICAL—CONTINUED				
5. Uses made of, and information found in, NavOrd OD3000	1	1	1	1
6. Purposes and types of entries made in ordnance histories	1	1	1	----
7. Types of information found in the following publications: OD, OP, OCL, OHI, OML, ORDALTS, and BuOrd Instructions and Notices	C	C	C	C
8. Purpose and scope of the BuOrd Manual as stated in chapter 1	C	C	C	C
9. Types of reports required by the Bureau of Ordnance concerning guns, mounts or turrets, and ammunition	C	C	C	C
10. Information shown in Current Ship's Maintenance Project (CSMP)	C	C	C	C

APPENDIX III

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3	Ammunition	101/8, 201/7, 202/8
4	Hydraulics & hydrostatics	202/14
5	Hydraulic mechanisms	102/15, 202/9, 202/13
6	The fire control problem	101/11
7	Fire control systems & techniques	101/11
8	Gun mounts—20mm to 5-in.	103/4, 202/12, 202/14
9	Breech mechanisms	102/13, 202/12, 202/14
10	Firing systems	102/13, 102/19, 201/6, 202/12
11	Recoil and counterrecoil	202/13, 202/14
12	Rocket launchers and projectors	101/10, 101/11
*13	Small-arms weapons and landing party gear	101/9, 102/12, 103/2, 202/15
*14	Small-arms ammunition and machine guns	101/9, 102/12, 103/2, 202/15, 202/16
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